

*Colloquium Abstract*  
*Stockholm Observatory and Uppsala University*  
*May 2007*

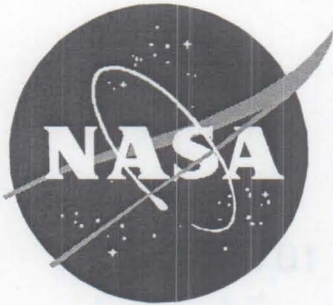
# High-Energy Astrophysics Overview

Dr. Gerald J. Fishman  
NASA - Marshall Space Flight Center  
&  
National Space Science and Technology Center (NSSTC)  
Huntsville, AL

## Abstract

High-energy astrophysics is the study of objects and phenomena in space with energy densities much greater than that found in normal stars and galaxies. These include black holes, neutron stars, cosmic rays, hypernovae and gamma-ray bursts. A history and an overview of high-energy astrophysics will be presented, including a description of the objects that are observed. Observing techniques, space-borne missions in high-energy astrophysics and some recent discoveries will also be described. Several entirely new types of astronomy are being employed in high-energy astrophysics. These will be briefly described, along with some NASA missions currently under development.

# High-Energy Astrophysics - An Overview



**Dr. Jerry Fishman**

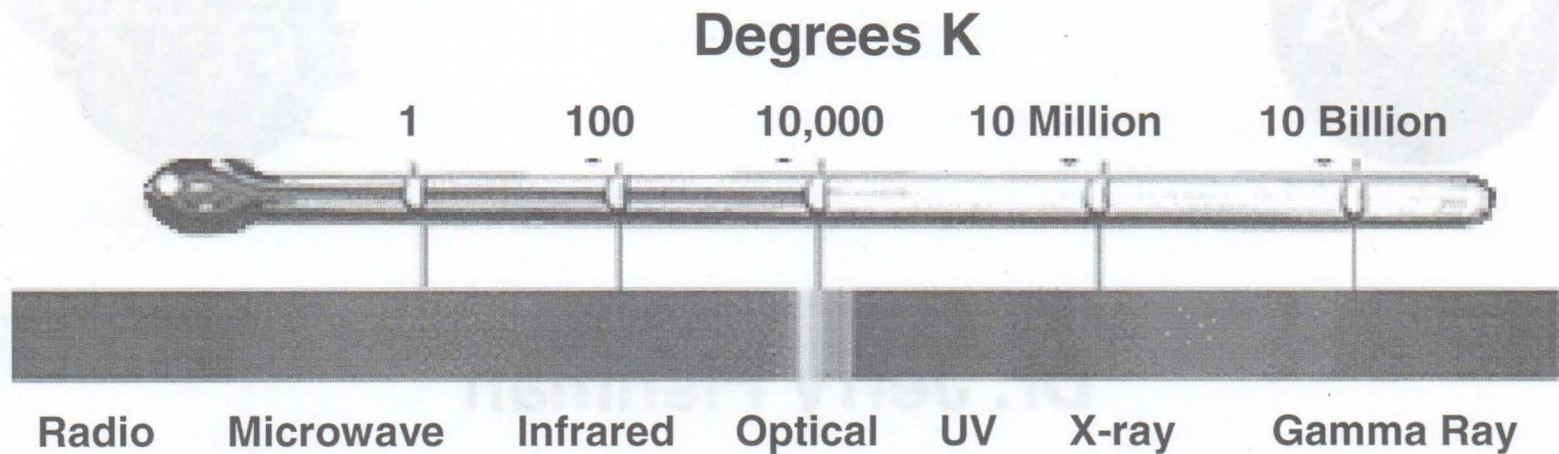
**NASA – Marshall Space Flight Center**

**National Space Science and Technology Center (NSSTC)**

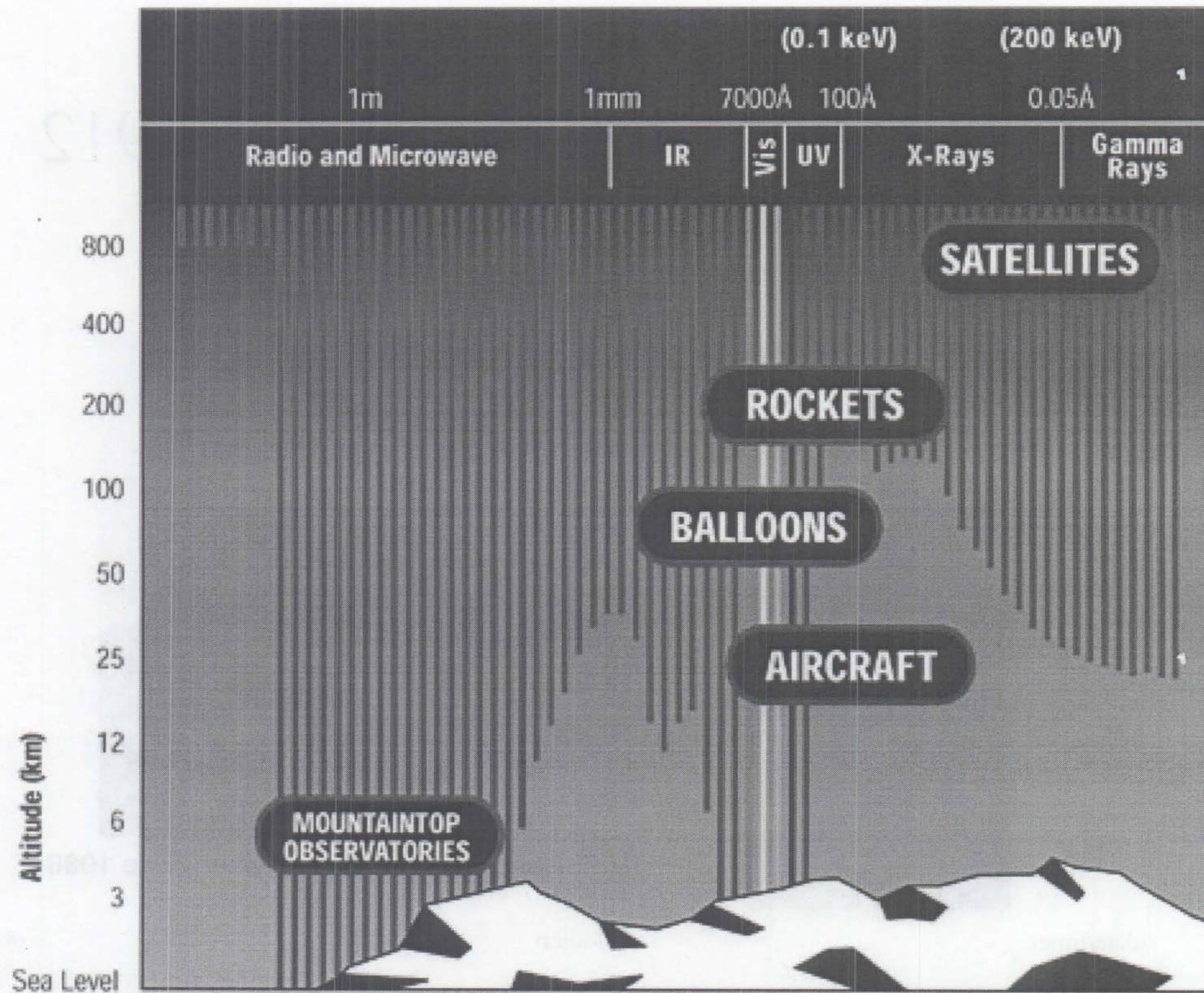
**Huntsville, AL**

*Sweden Presentation - May 2007*

# Electromagnetic Spectrum / Temperature Scale



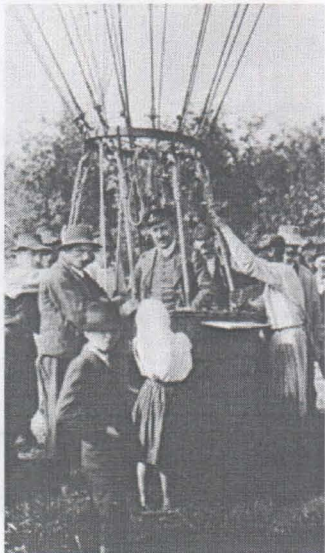






# Discovery of Cosmic Rays - 1912

- In a balloon, at an altitude of 5,000 meters Victor Hess, the father of cosmic ray research, discovered "penetrating radiation" coming from space.



<date/time>

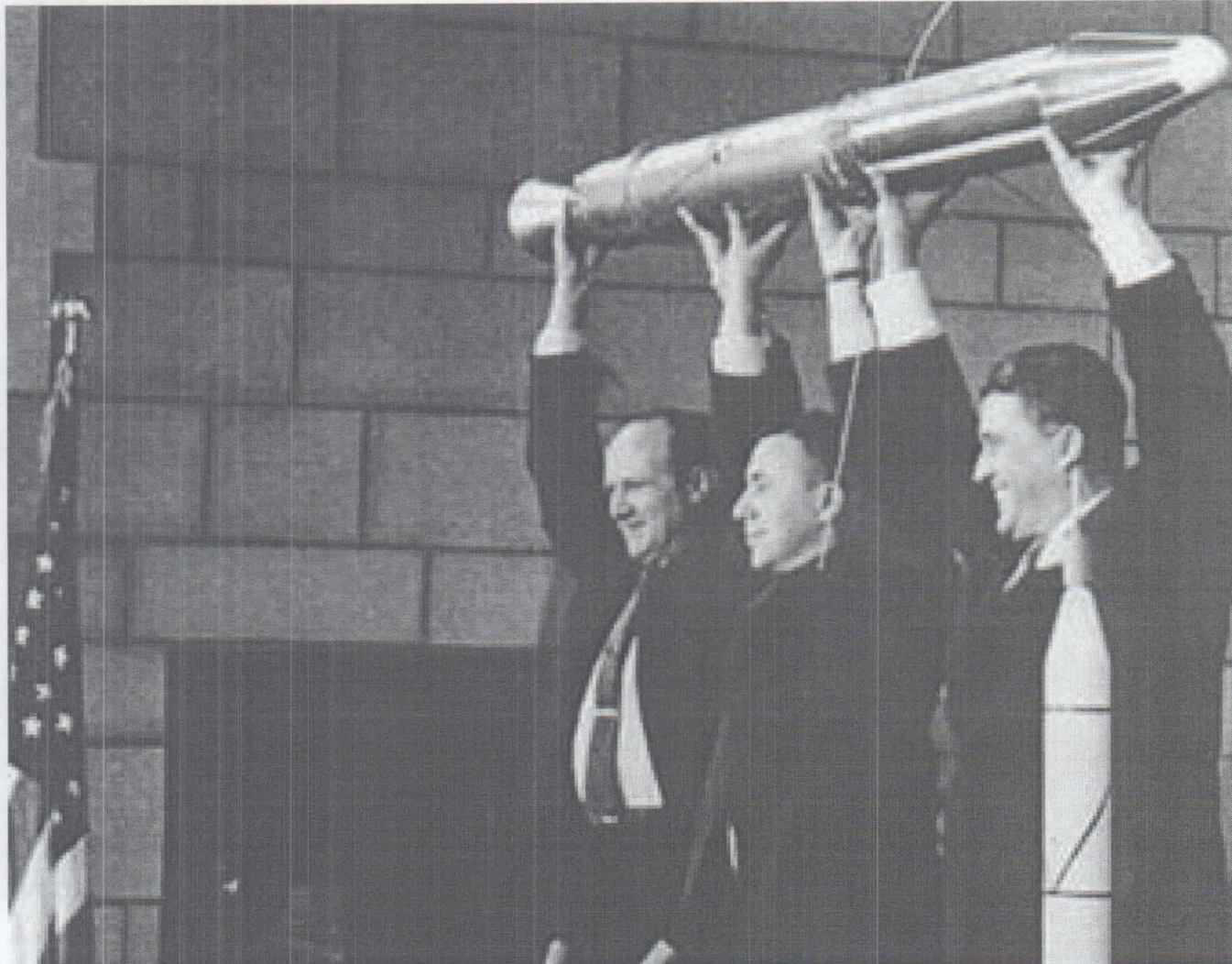


**V.F. Hess (1883-1964) – Nobel Prize 1936**

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Dr. von Braun, Dr. Van Allen & Dr. Pickering  
Holding a Model of Explorer 1 after its Successful Launch

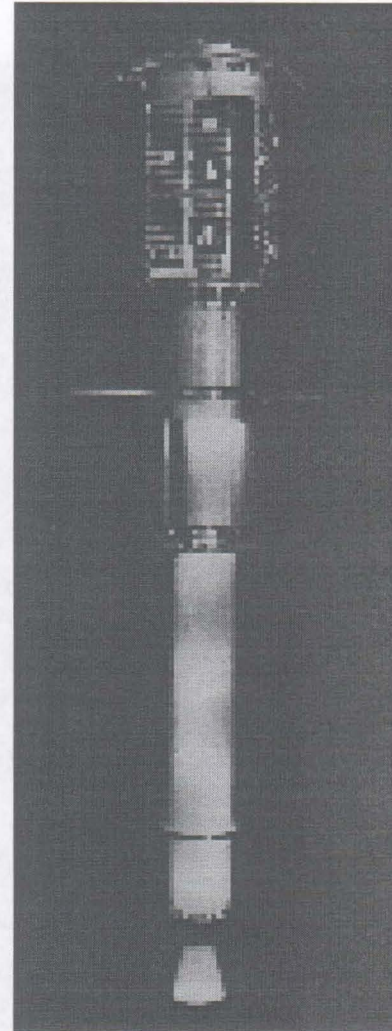




# Explorer-11

- **First Gamma-Ray Astronomy  
Experiment in Space – 1961**

- **Detected 22 gamma-rays !**
- **Discovered Galactic  
Distribution**
- **S:N ~ 1:1000**





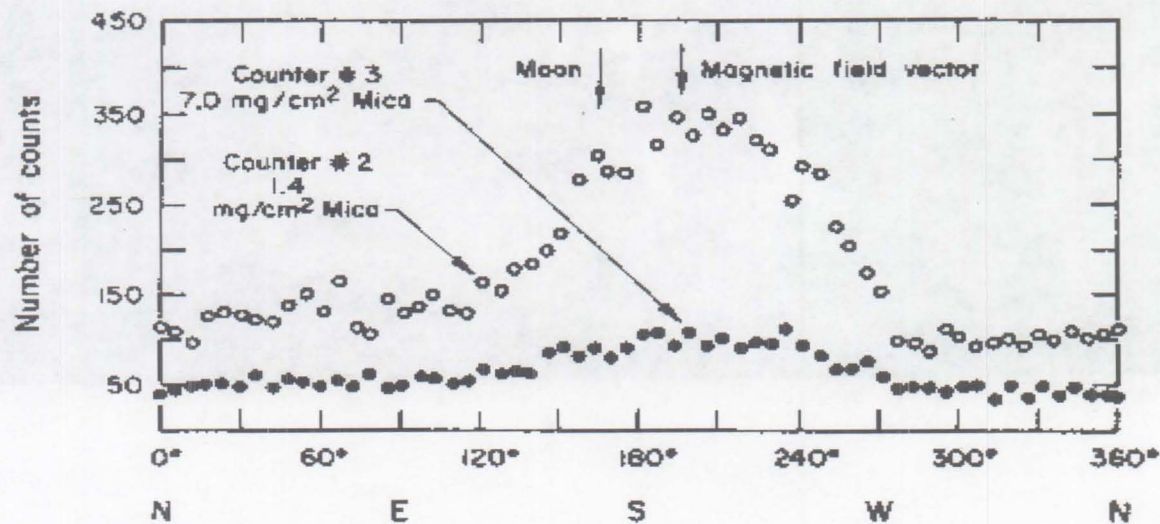
# Discovery of a Cosmic X-ray Source (Sco X-1)

by AS&E/MIT Group

1962

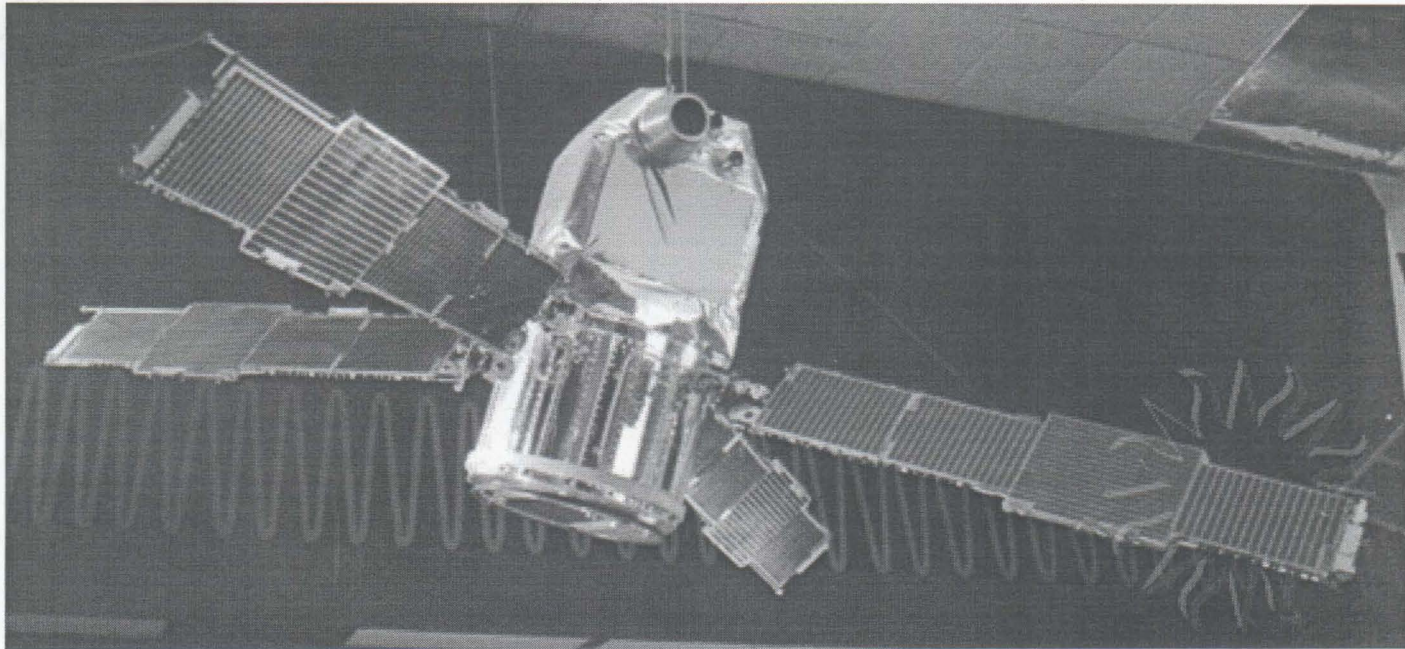


R. Giacconi  
2002 Nobel Laureate



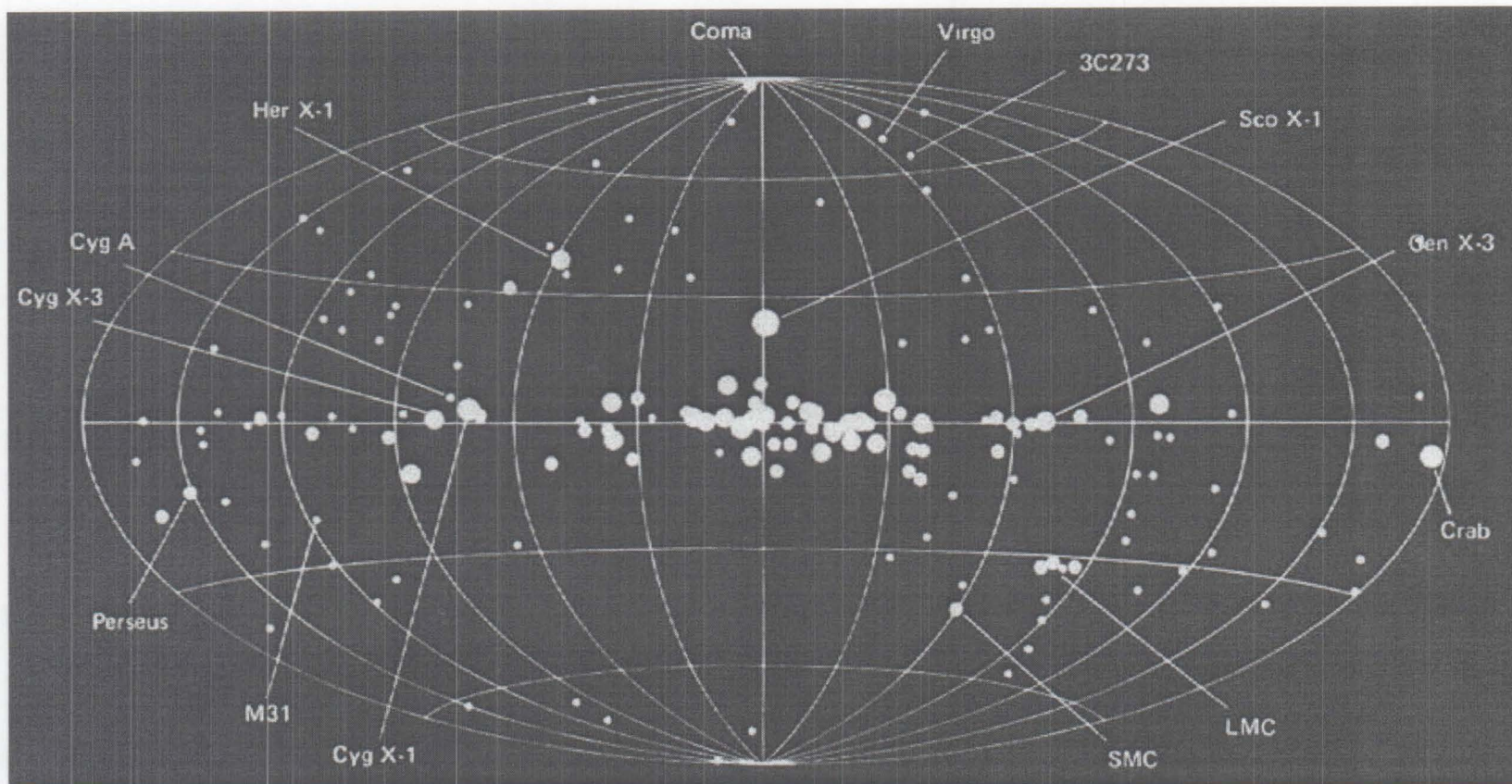
# UHURU – Explorer Spacecraft

First X-ray Astronomy Satellite  
1970-1974





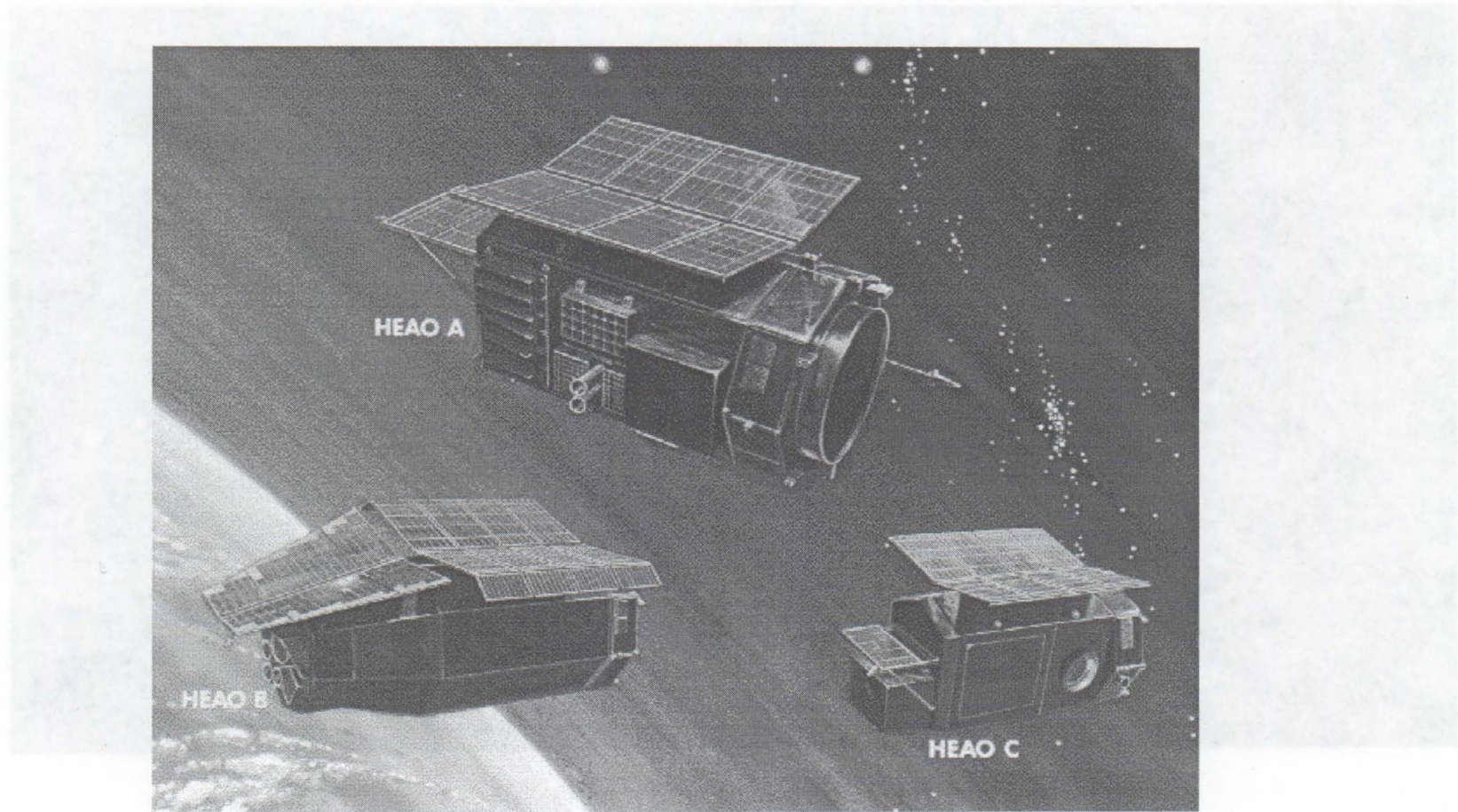
# UHURU Sky Map





# HEAO Program: 1978 - 1982

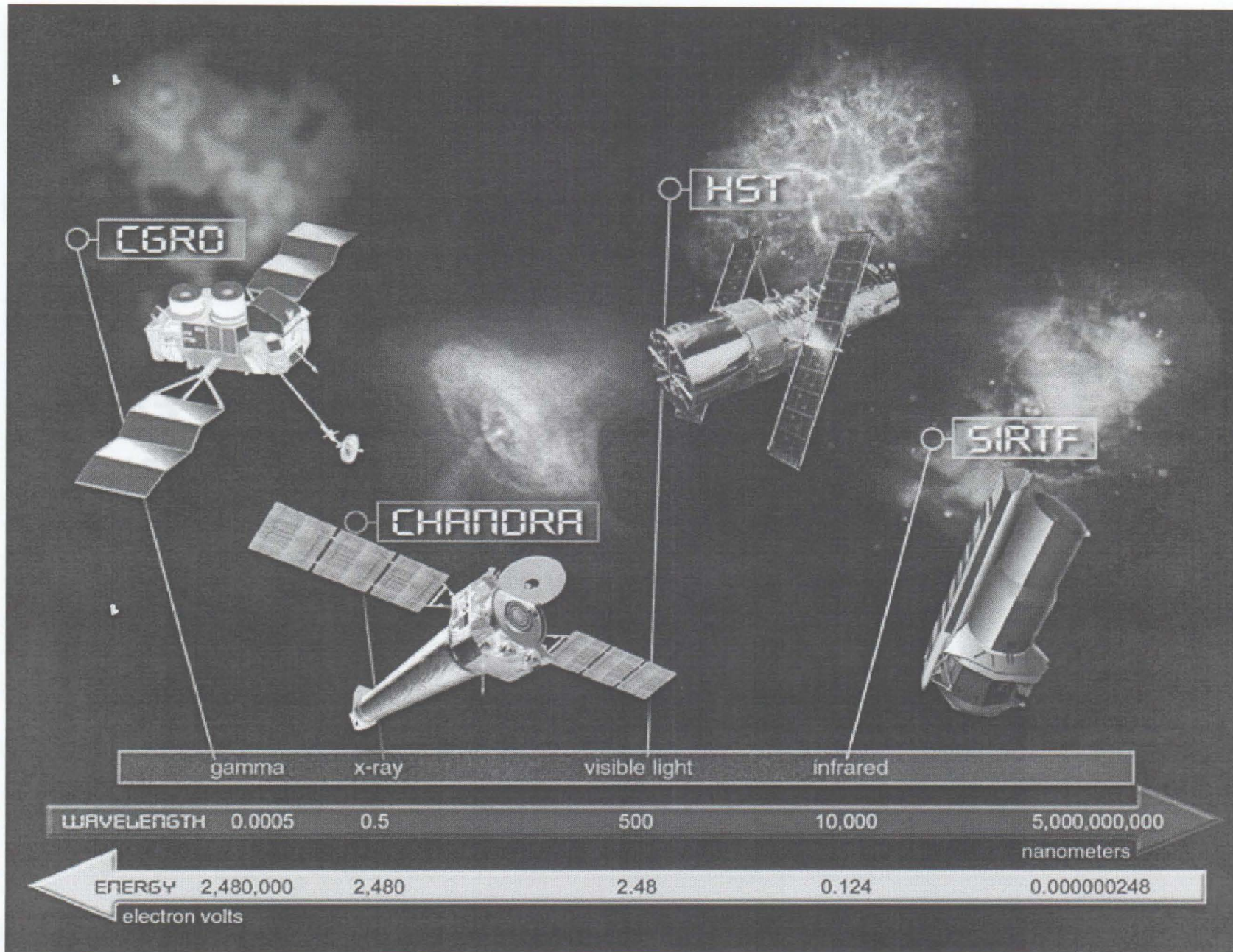
High Energy Astronomy Observatory



# **NASA's Great Observatories :**

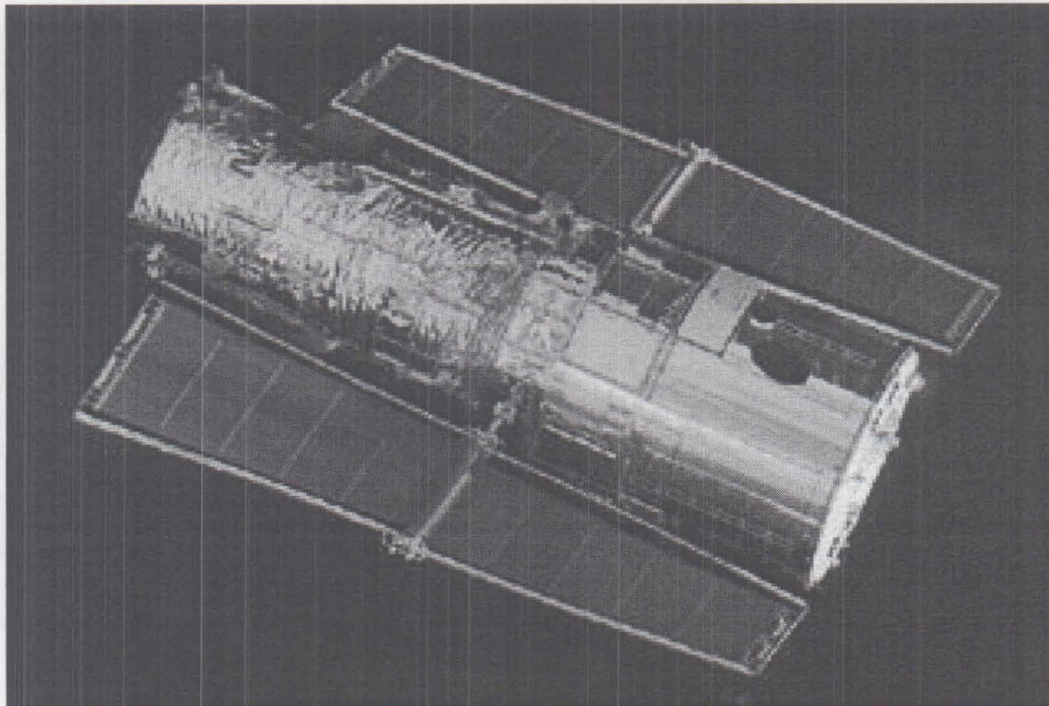
	<b>Year</b> <b><u>Launch - End</u></b>
<b>Hubble Space Telescope</b>	<b>1990 - ~2009?</b>
<b>Compton Gamma-Ray Observatory</b>	<b>1991 - 2000</b>
<b>Chandra X-Ray Observatory</b>	<b>1999 - ~2020?</b>
<b>Spitzer Space Infrared Telescope</b>	<b>2003 - ~2007</b>





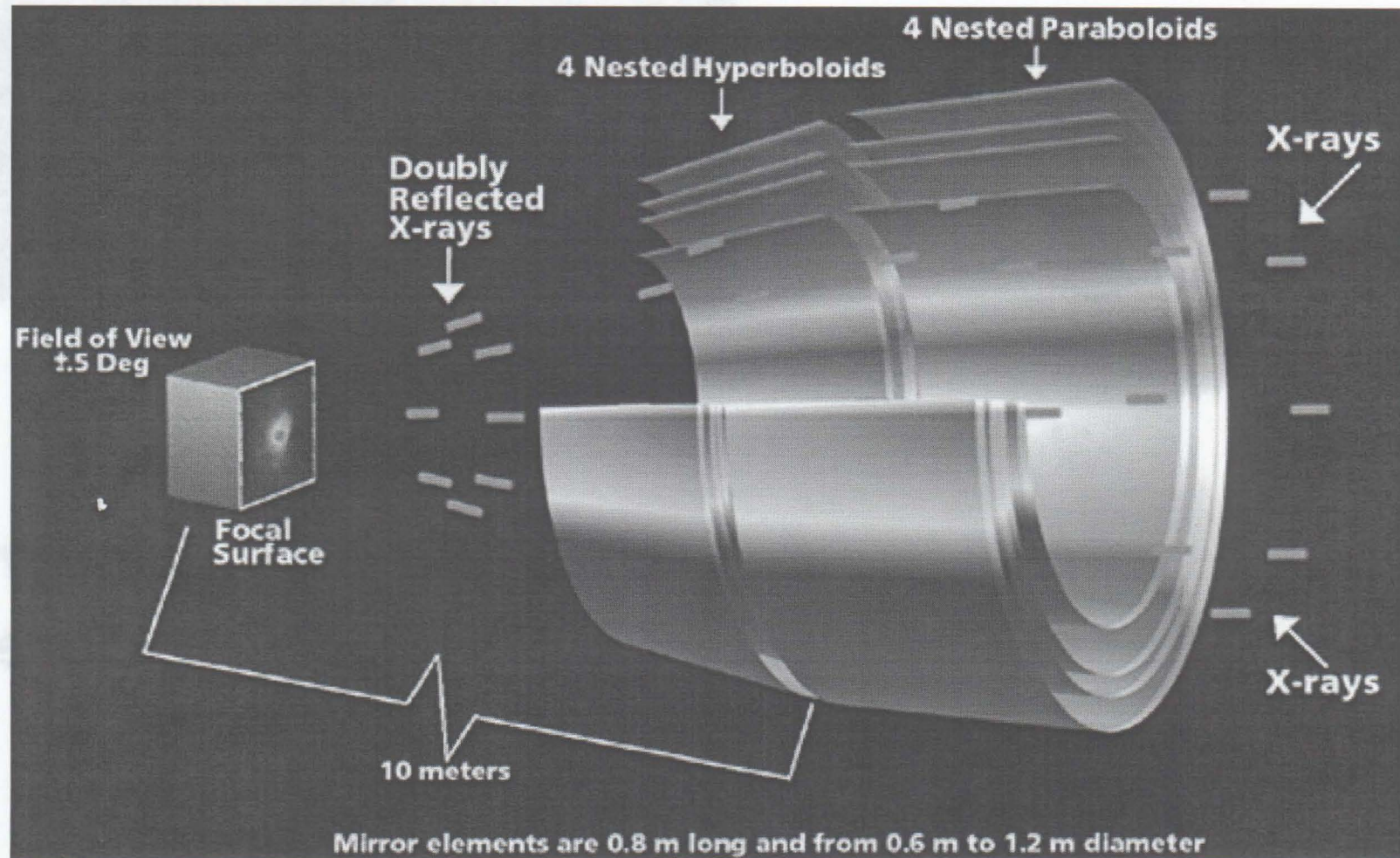


**Hubble  
Space Telescope  
(HST)**



**M-87  
Core  
&  
Jet**

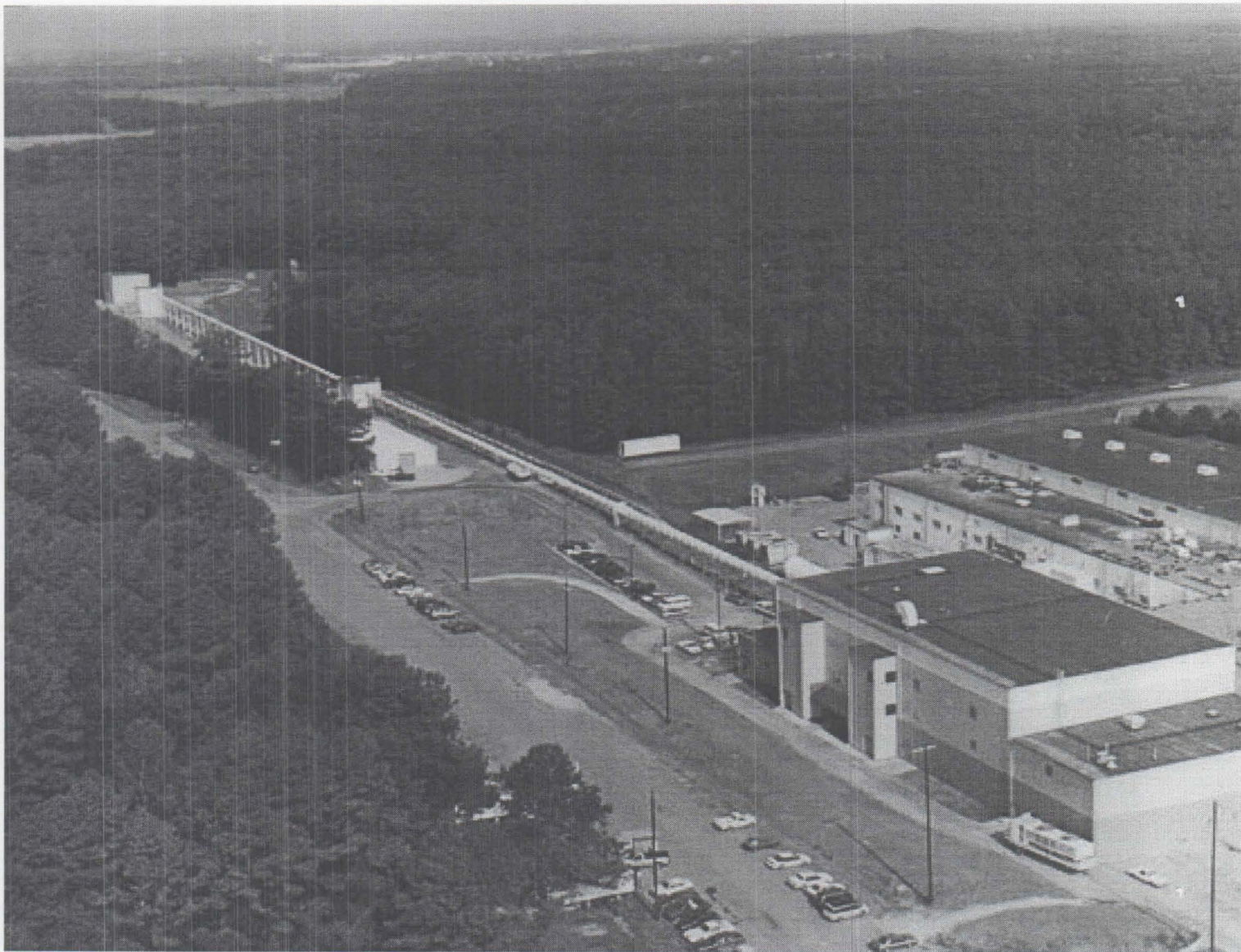
# Chandra Optics





# **X-ray Calibration Facility, NASA-MSFC**

## **Huntsville, AL**





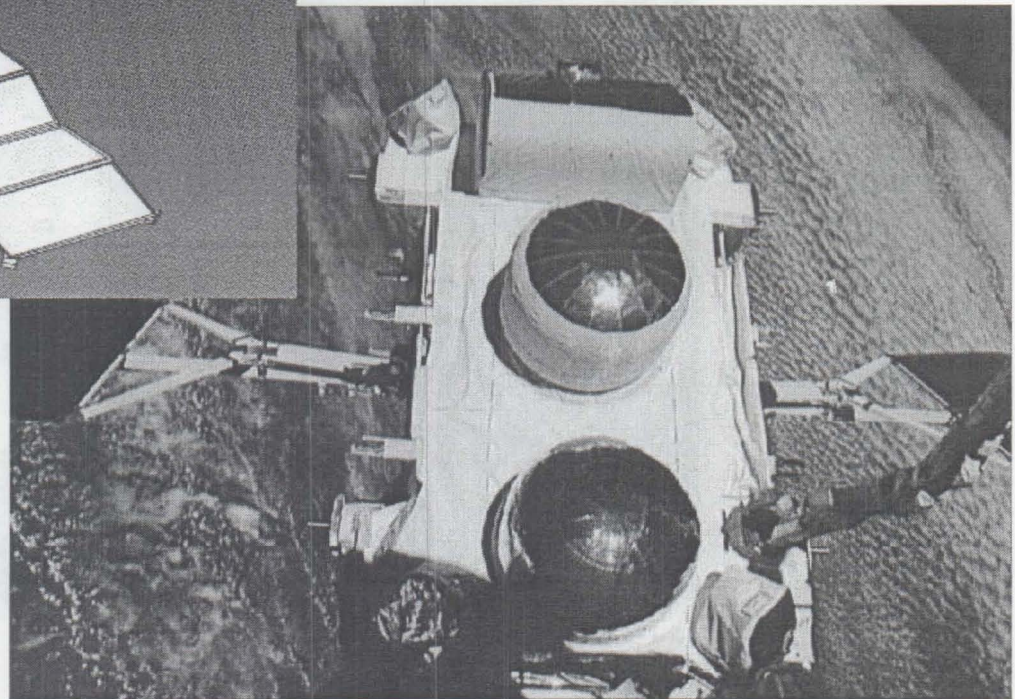
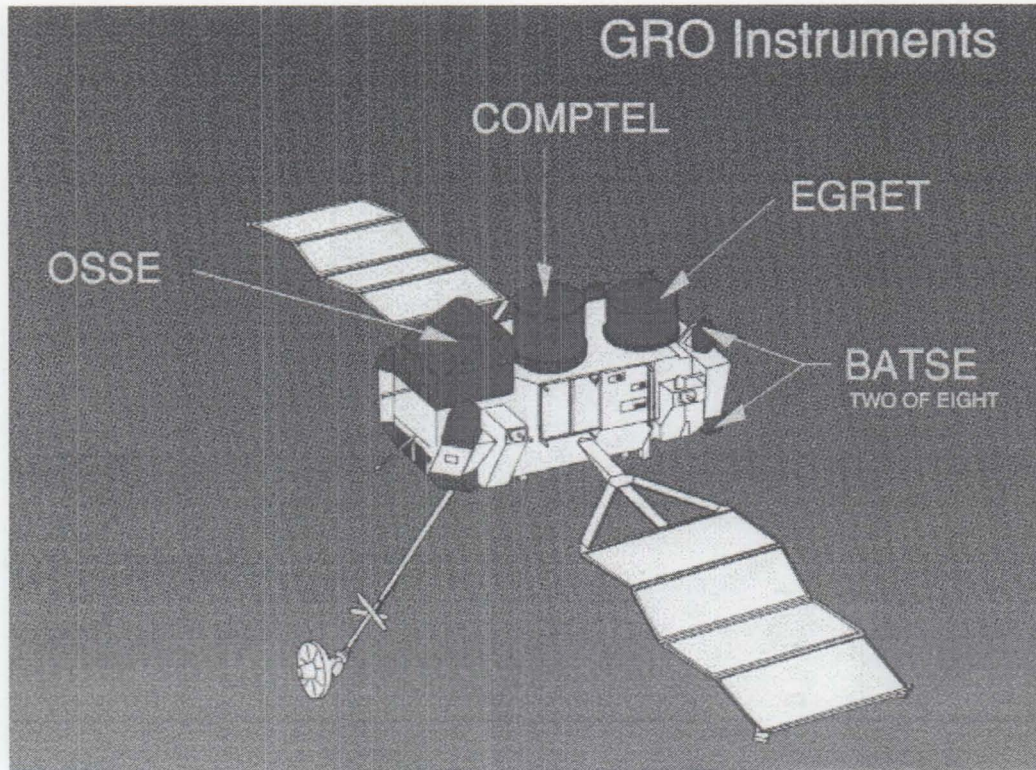
# The Crew





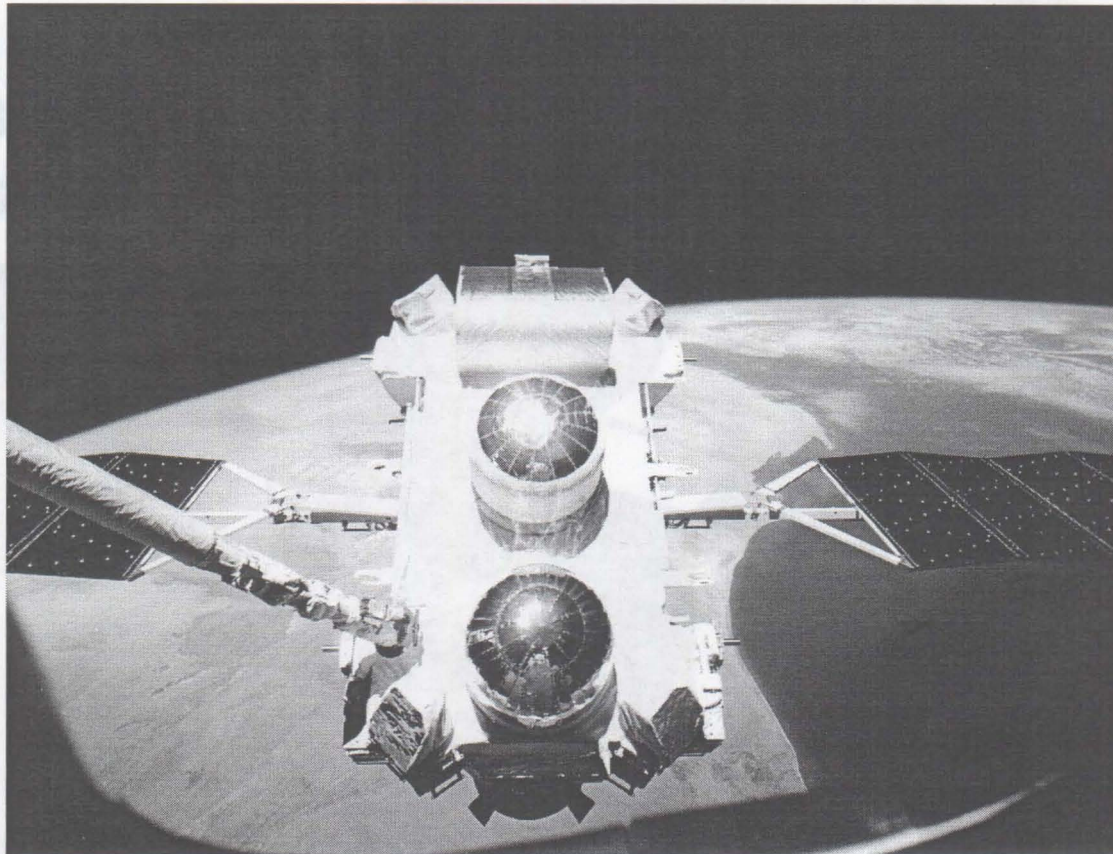
# Compton GRO

(Gamma-Ray  
Observatory)



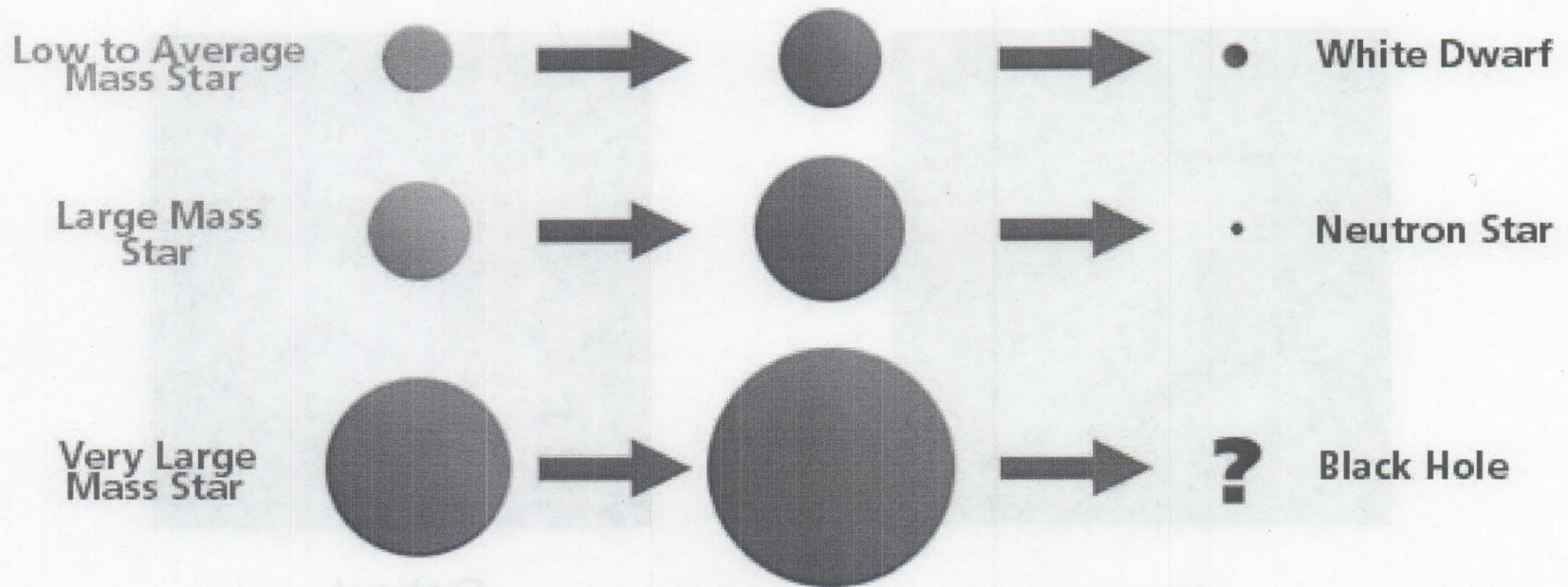


# Compton GRO –In Orbit



# Stellar Evolution

- \* More massive stars evolve faster
- \* The fate of a star depends on its mass



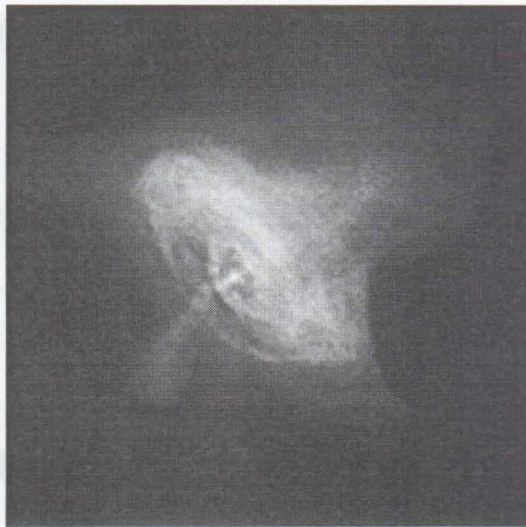
The fate of a star depends on its mass (size not to scale)



# The Crab Nebula

A Star that Exploded in 1054 AD

> Supernova <

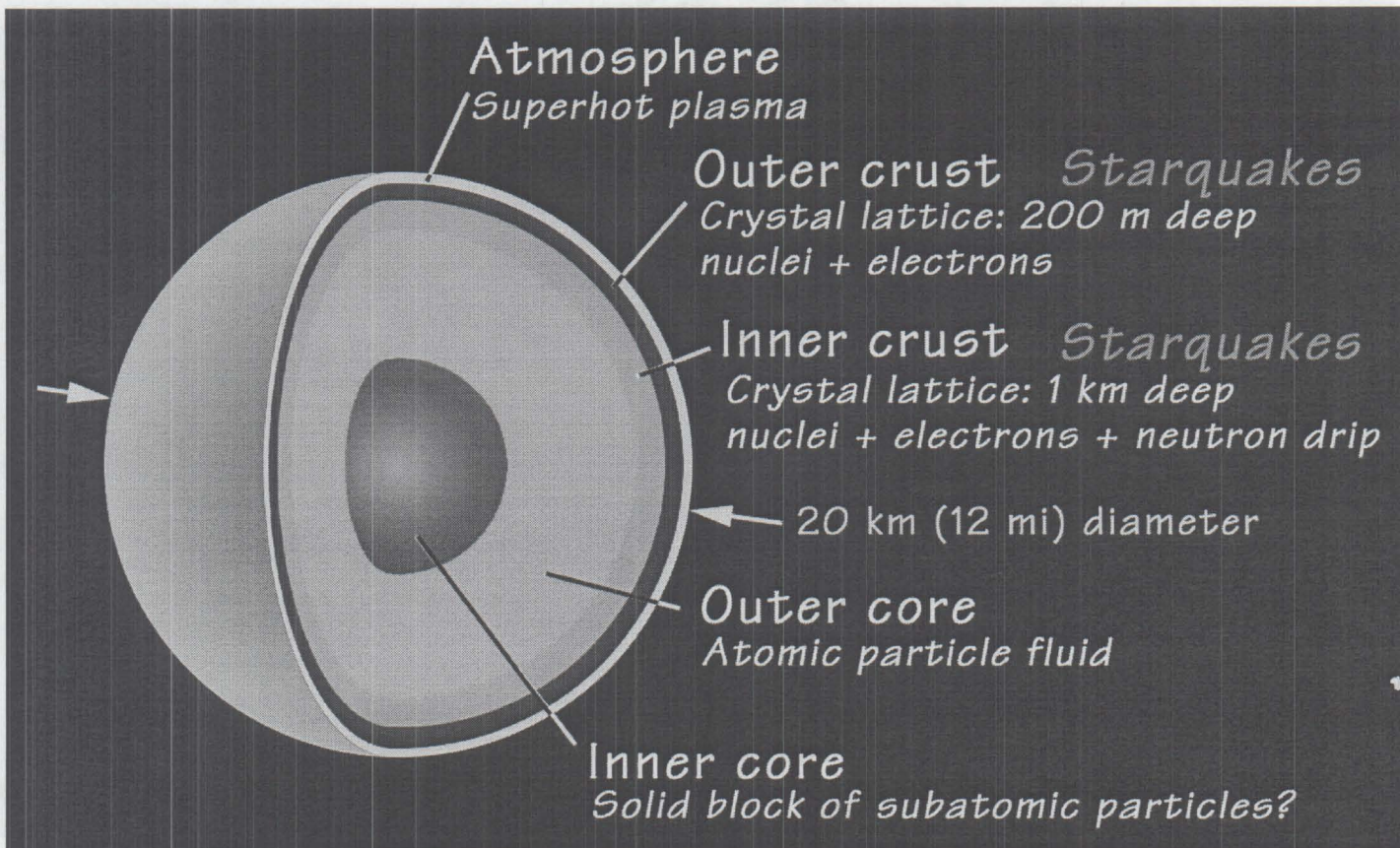


**X-ray**  
**(Chandra)**



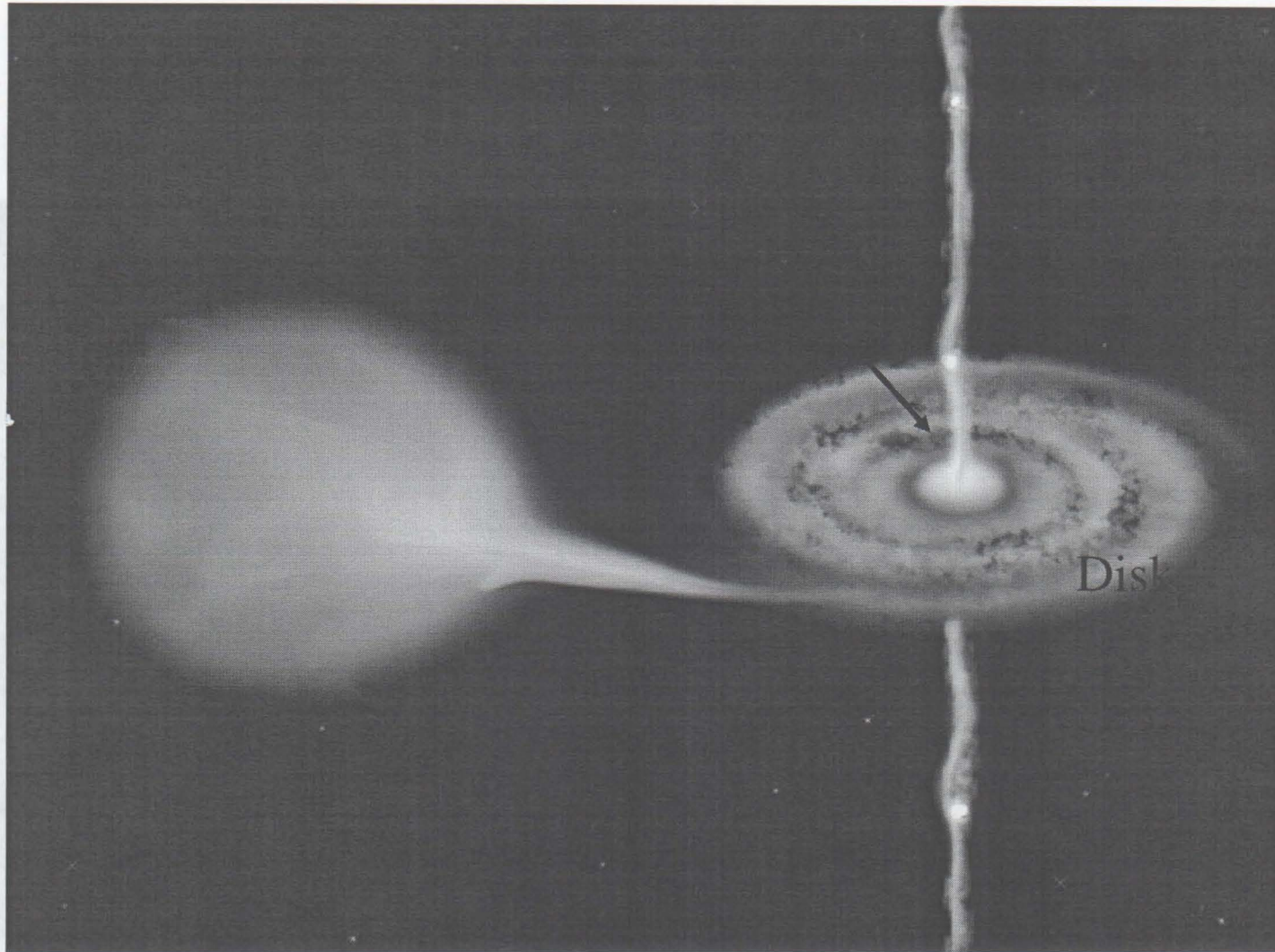
**Optical**  
**(Hubble)**

# Neutron Star – cross section





# X-ray Binary Systems

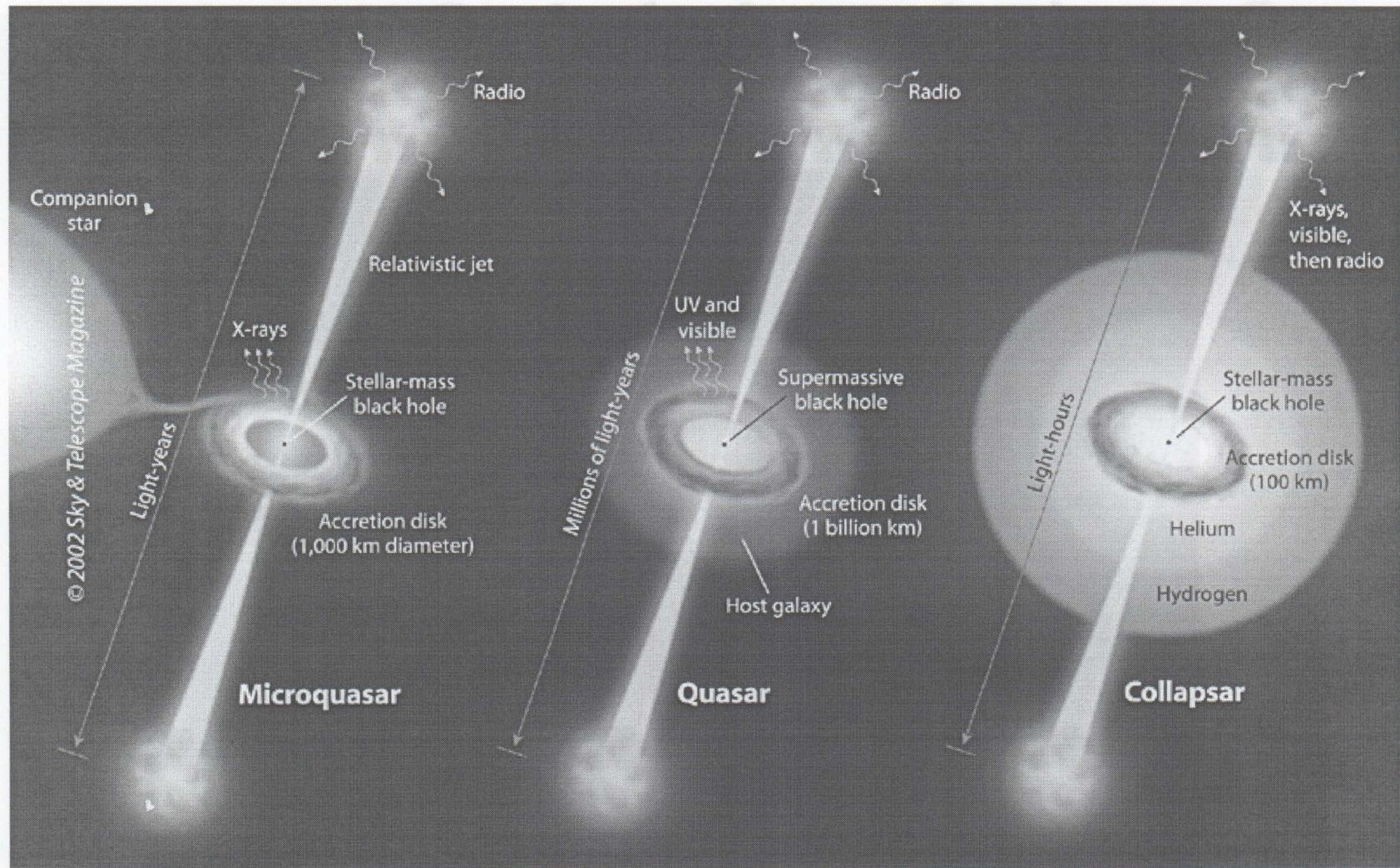


# Cosmic Jet – Artist's Concept





# A UNIVERSAL MECHANISM



**Microblazar**

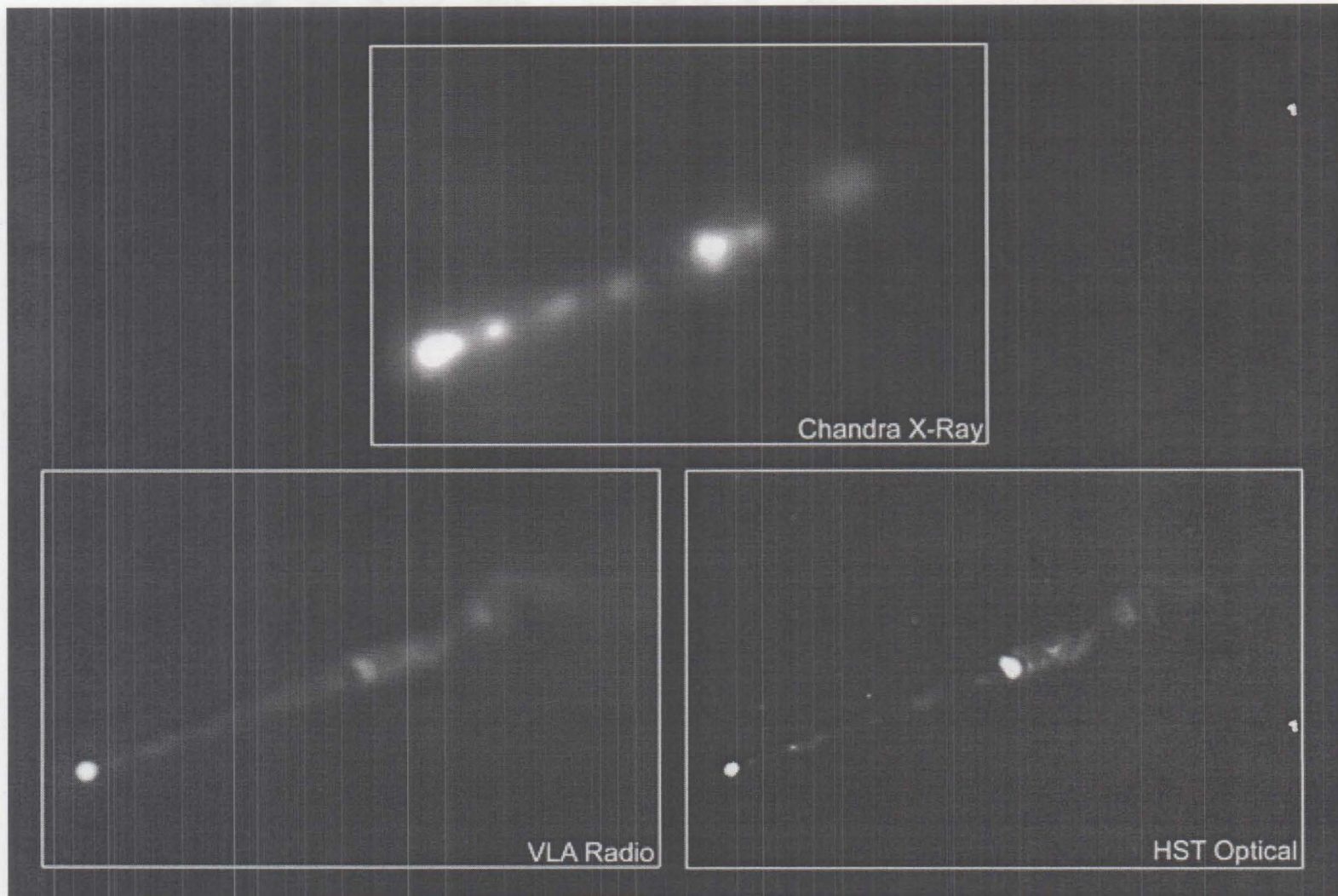
**Blazar**

**GRB**

(Mirabel & Rodriguez; Sky & Telescope, May 2002)



# Multi-wavelength Jets: M87

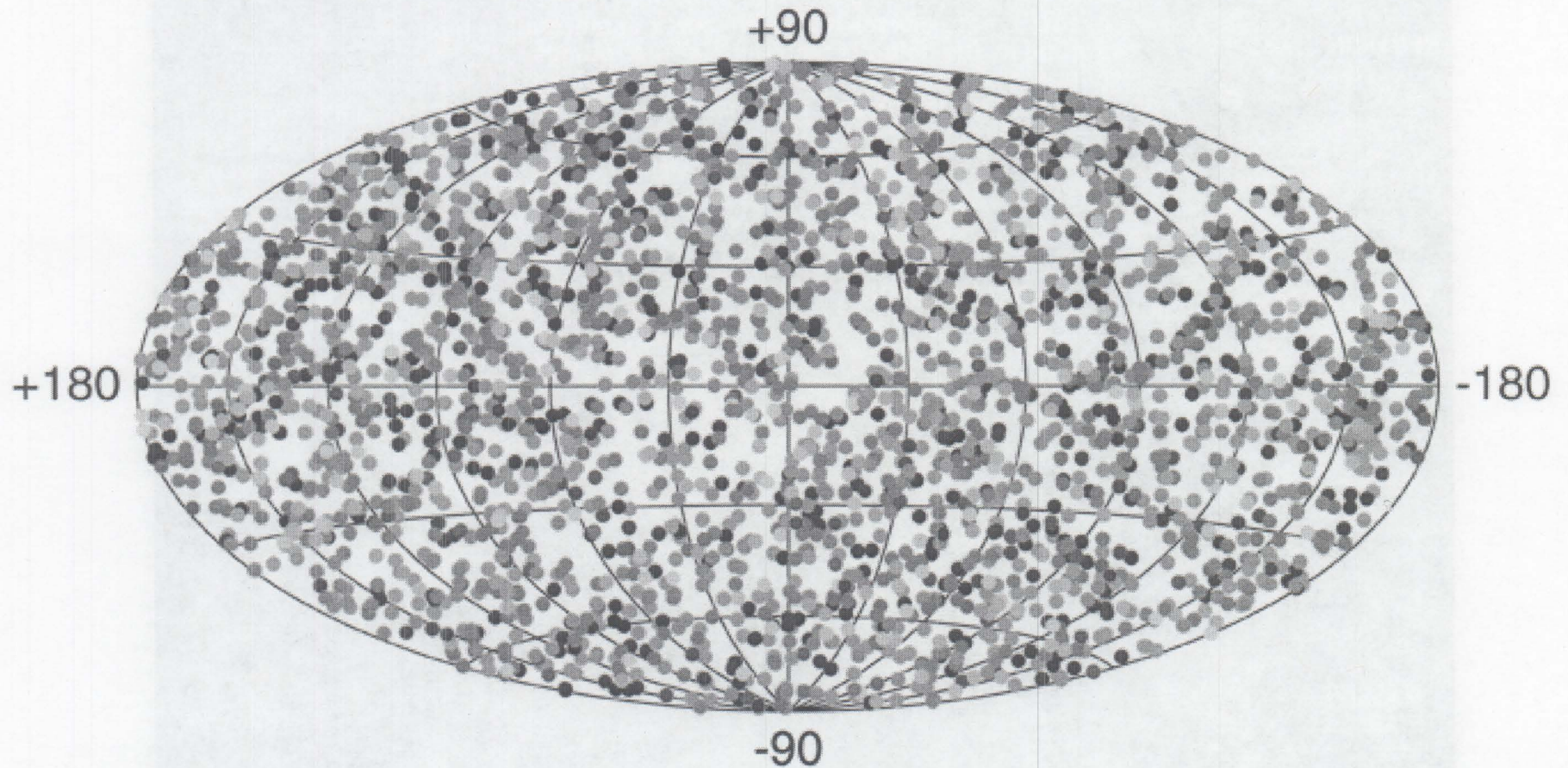




# **Gamma-Ray Bursts**

- **The Most Powerful Explosions in the Universe**
- **BATSE's Primary Objective**

# 2704 BATSE Gamma-Ray Bursts

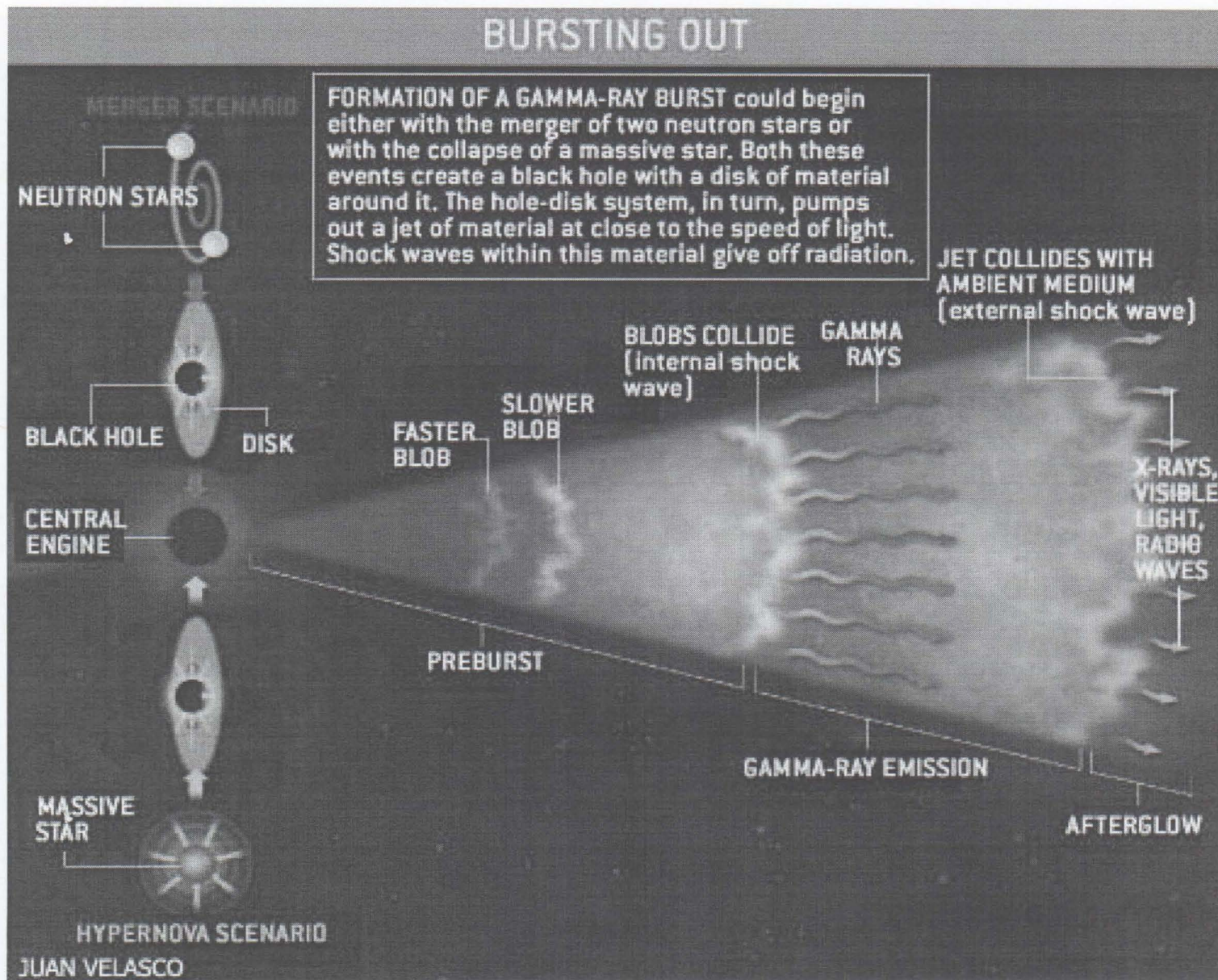


(Galactic Coordinates)

Apr. 1991 – May 2000

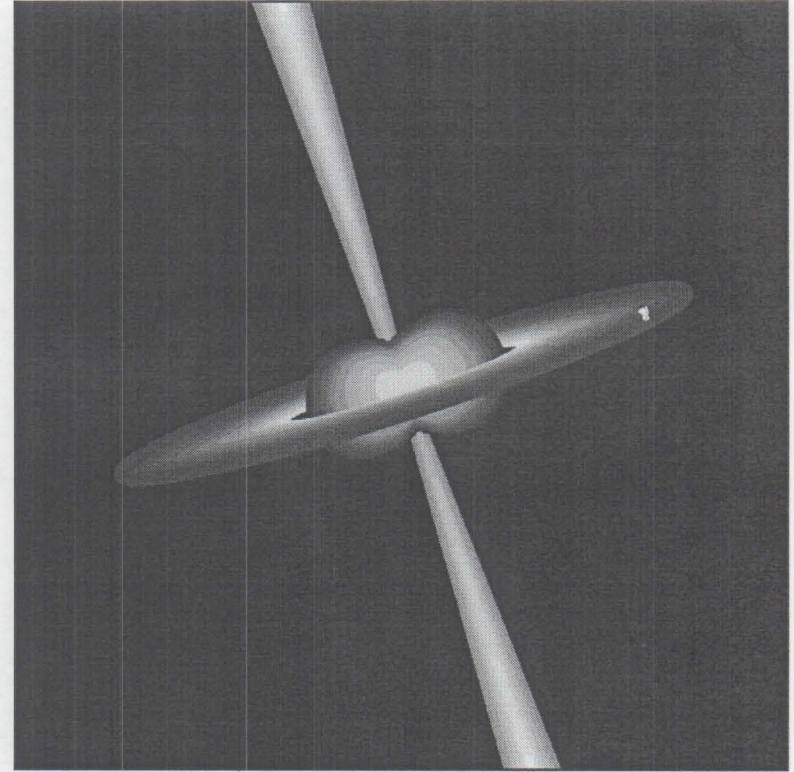
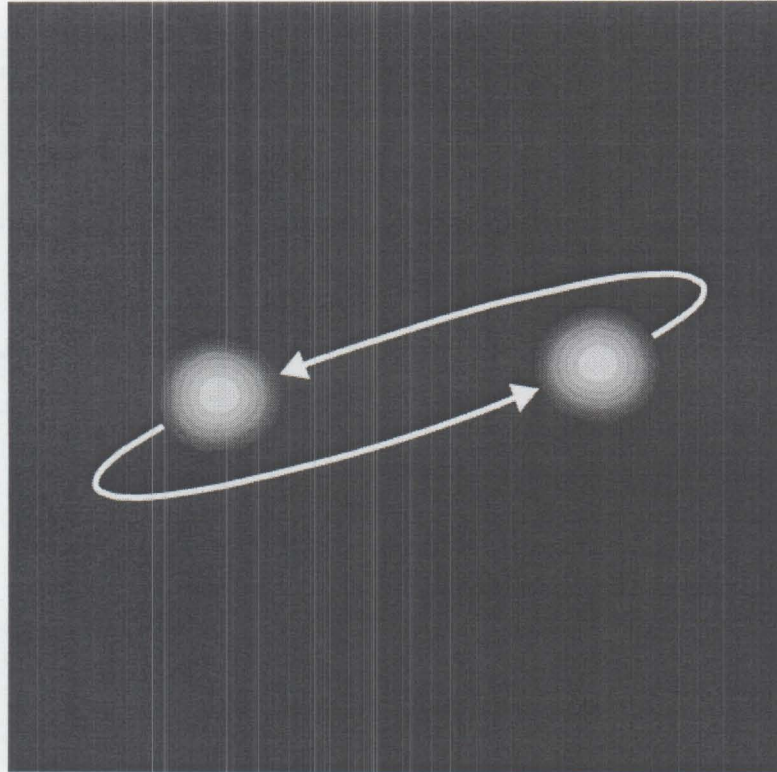


# Gamma Ray Bursts - Theories



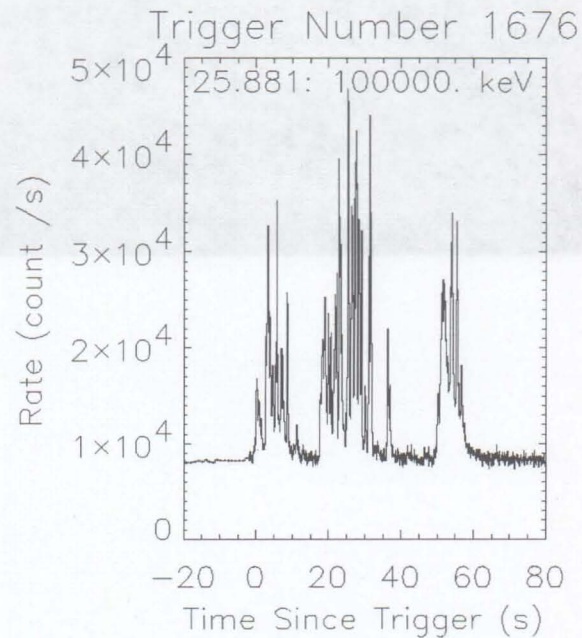
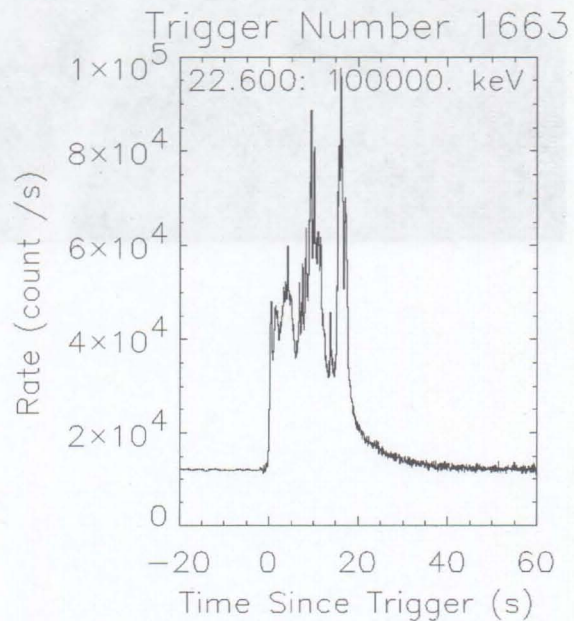
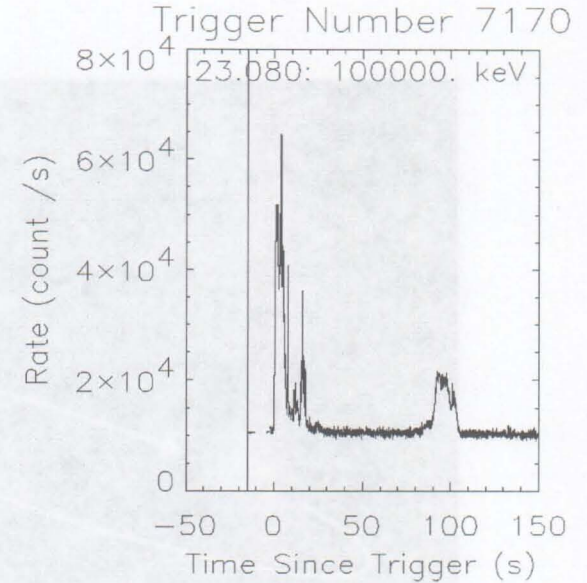
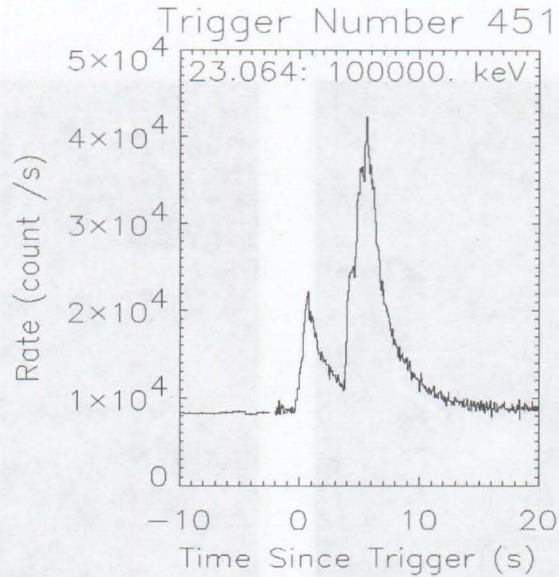
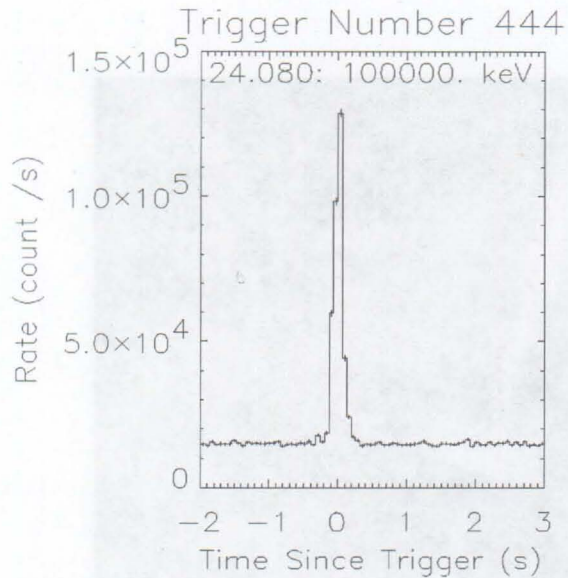


# Merging Neutron Stars

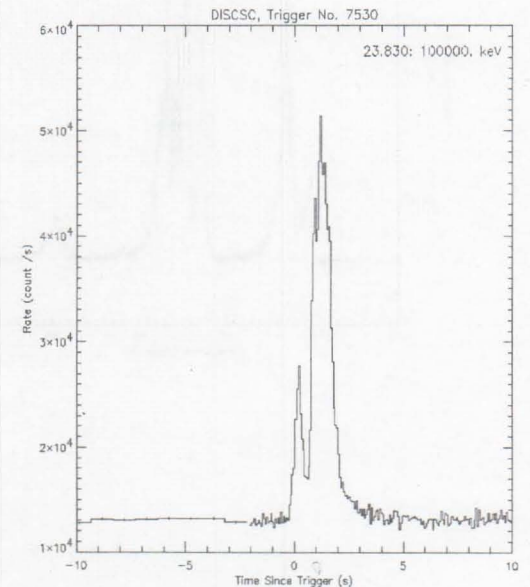
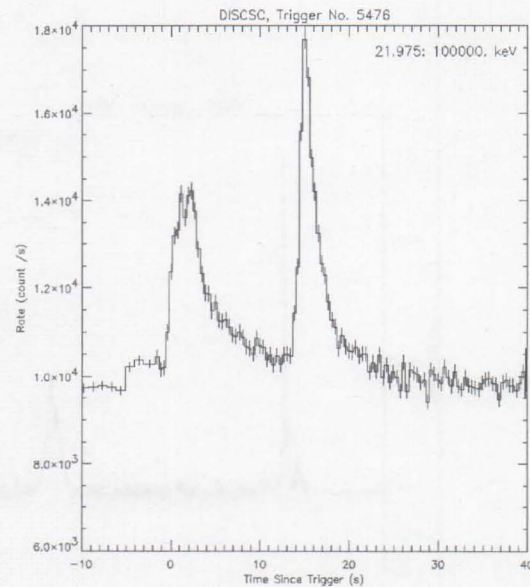
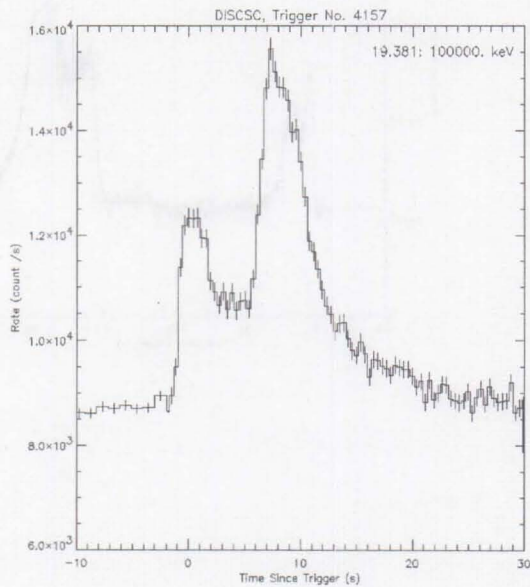




# Diversity of GRB Profiles

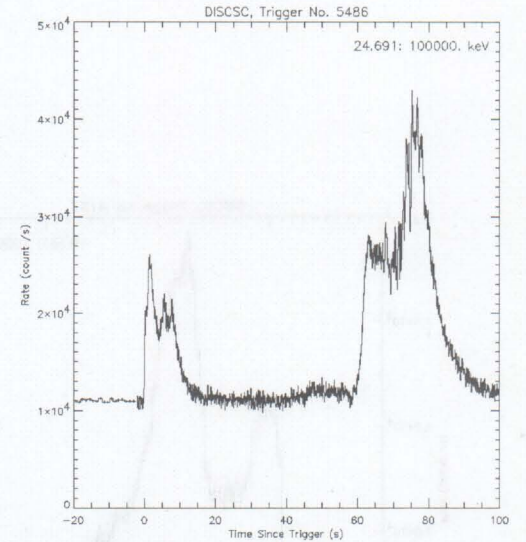
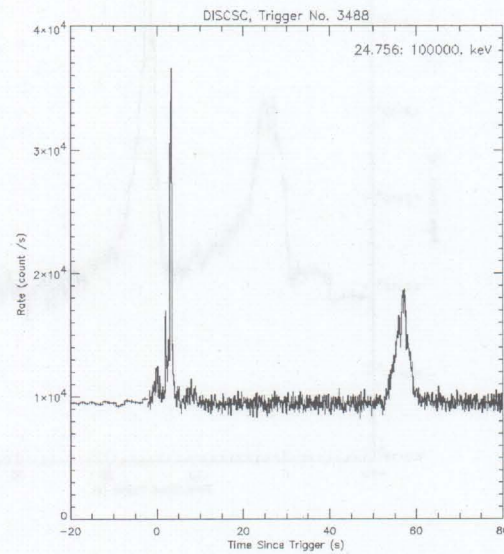
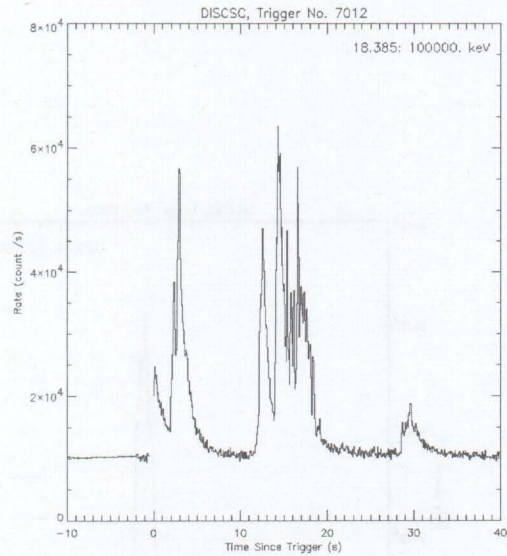


# Examples of Double-Peaked GRBs

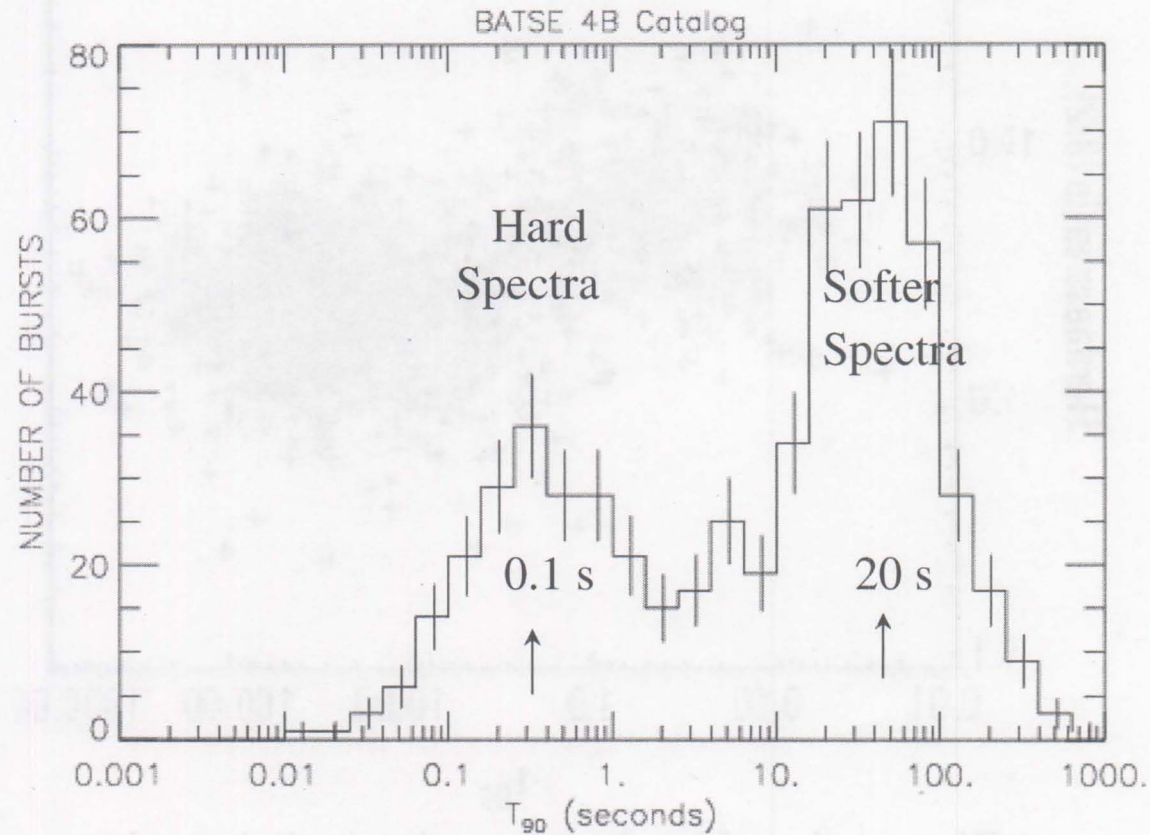




# Multiple-Episode Bursts



# Distinct subclasses of $\gamma$ -ray bursts: short/hard & long/soft





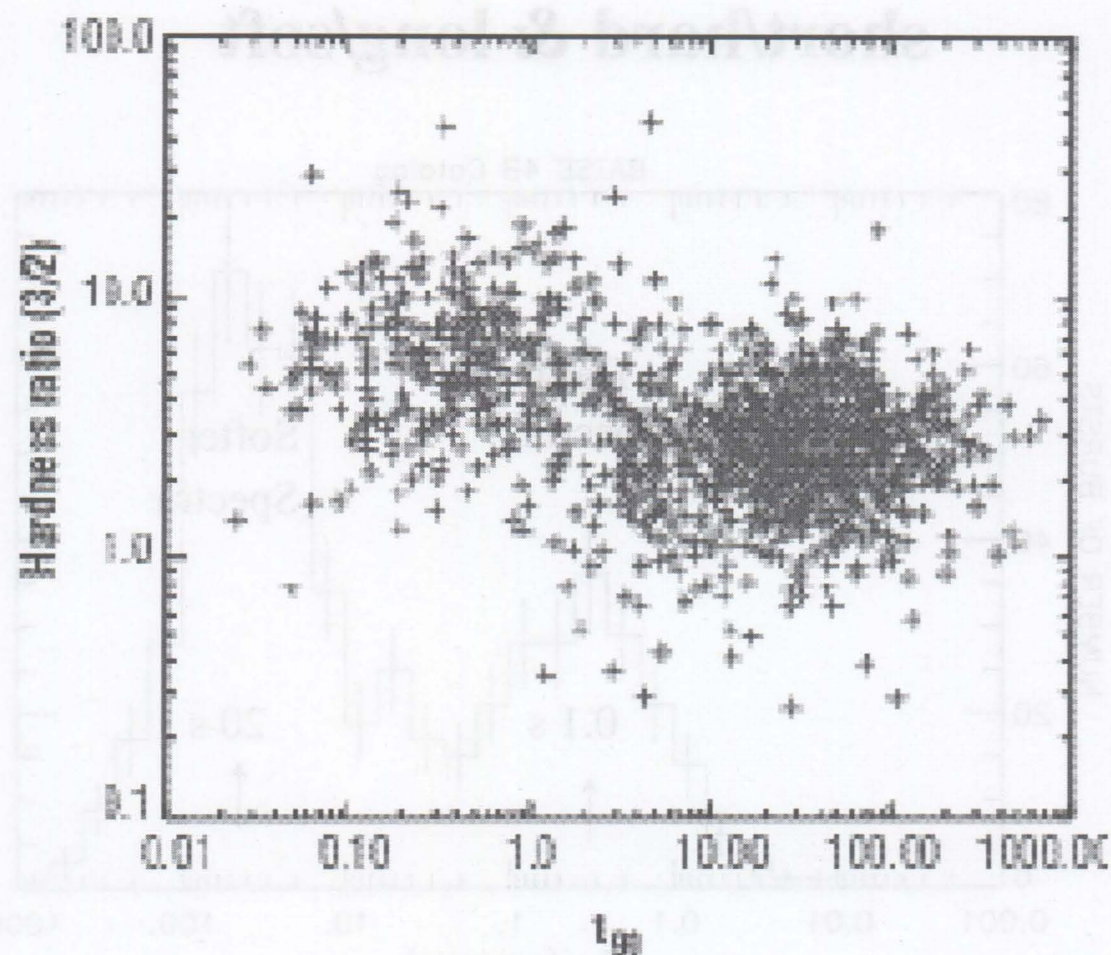
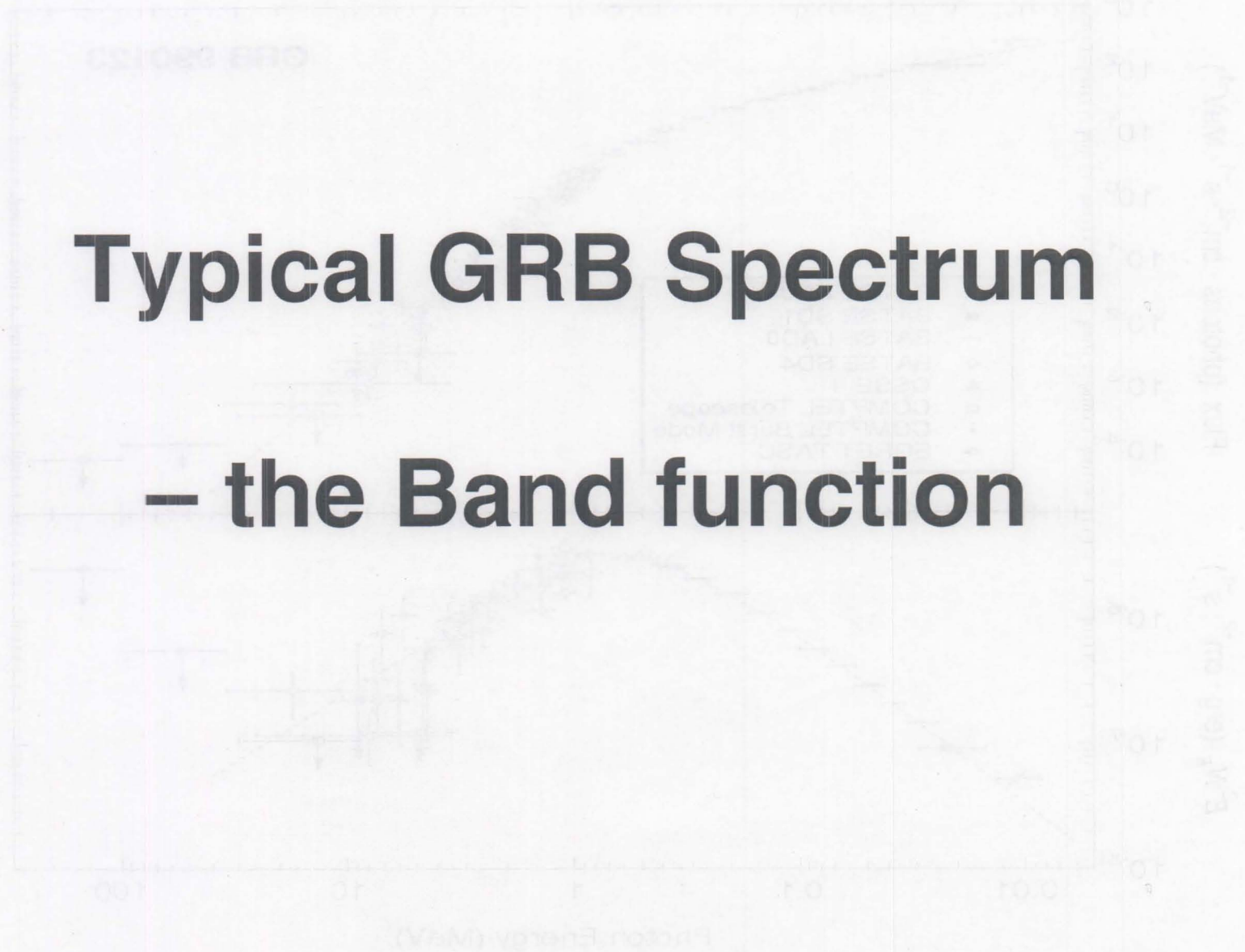


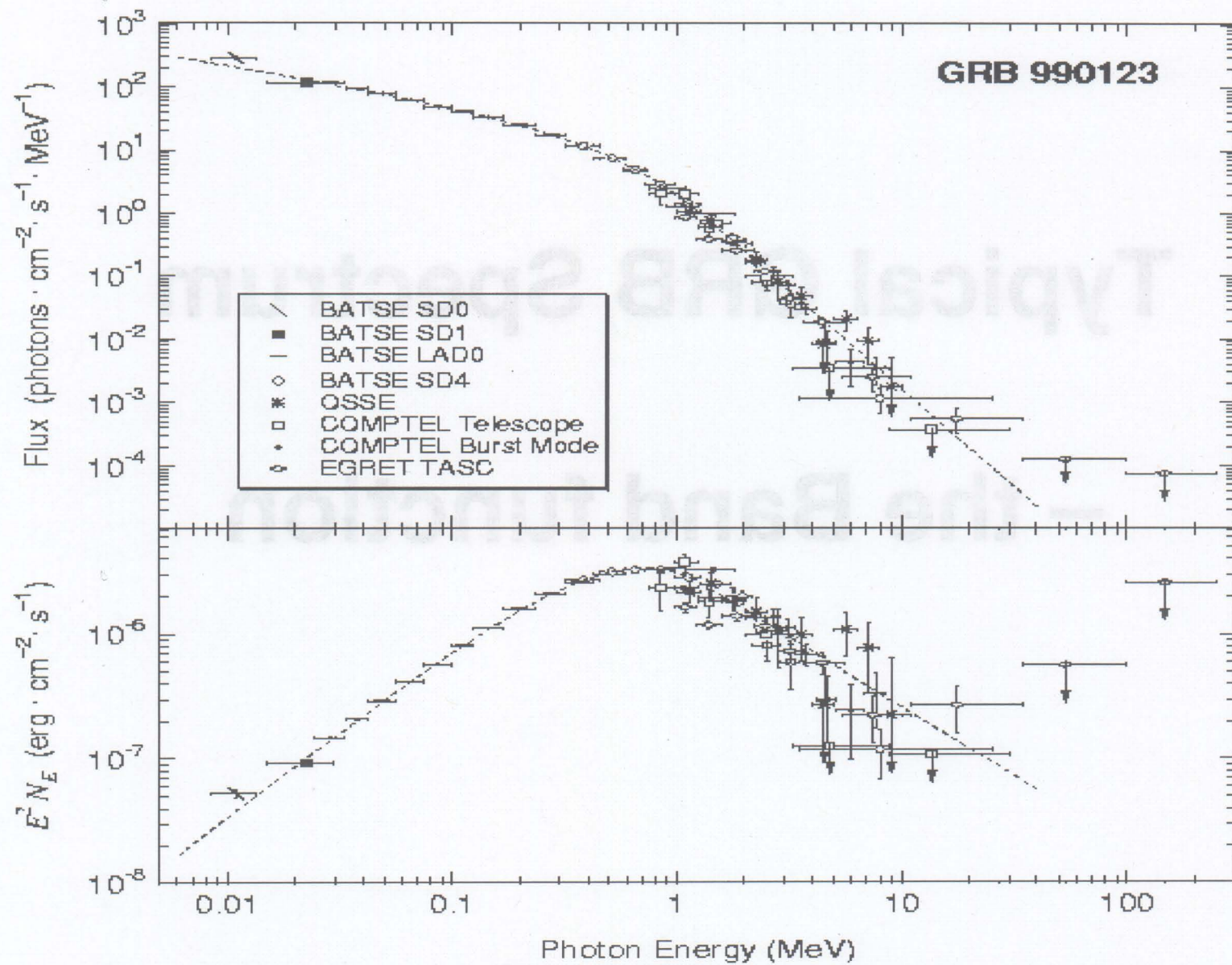
Figure 4.—Hardness-ratio and duration characteristics of GRB's. When GRB's are plotted against hardness ratio and duration, two classes become evident: short/hard and long/soft.

# Typical GRB Spectrum

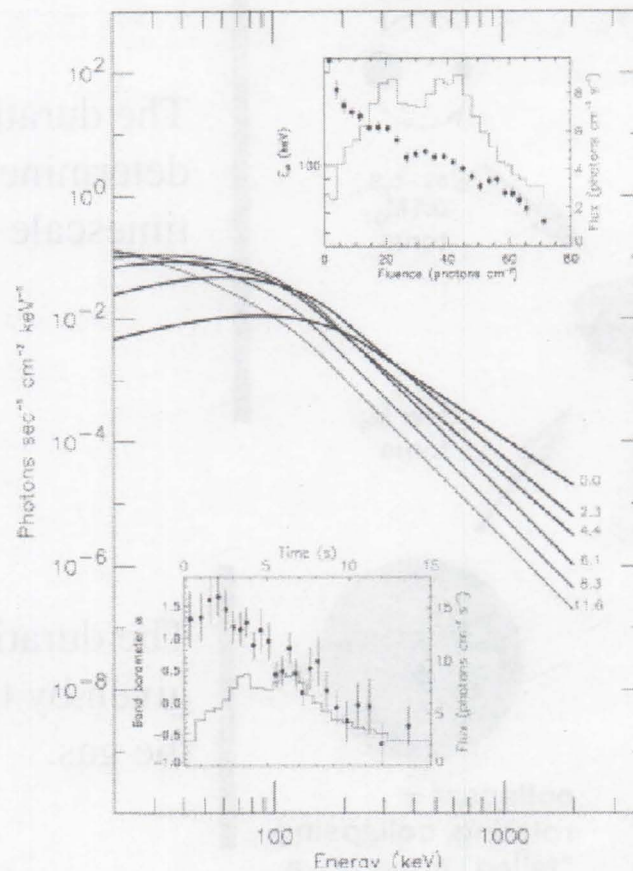
## – the Band function







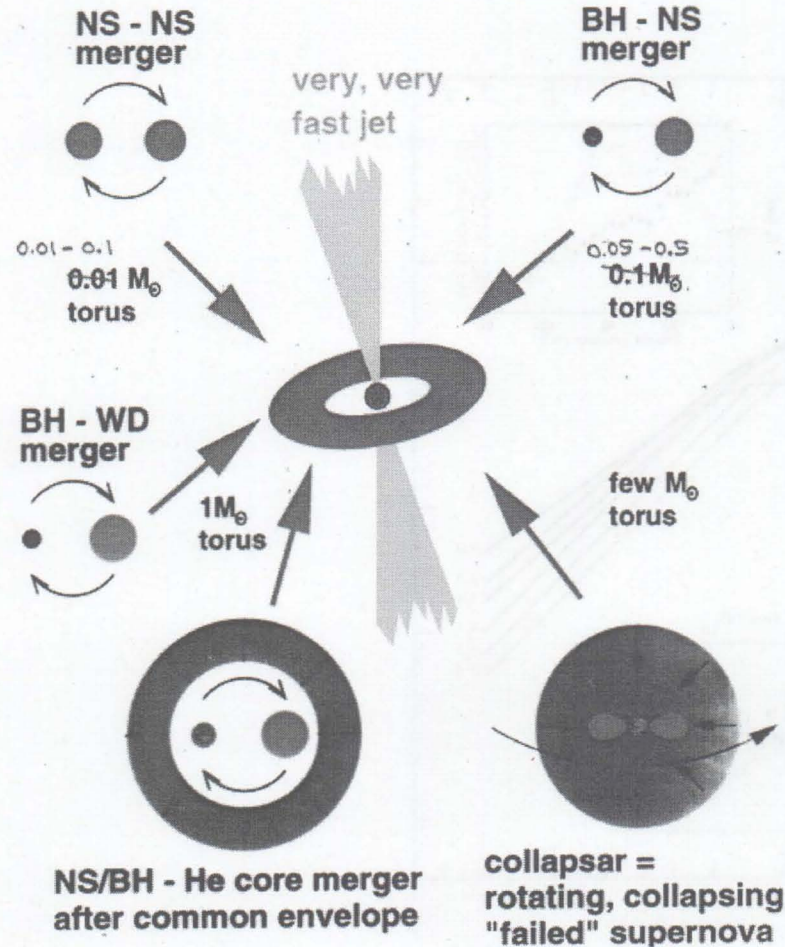
# Spectral Evolution of GRBs



-from Crider, et al. 1997



# What is the trigger?



The duration of the burst is determined by the viscous timescale of the accreting gas

The duration of the burst is given by the fall-back time of the gas.

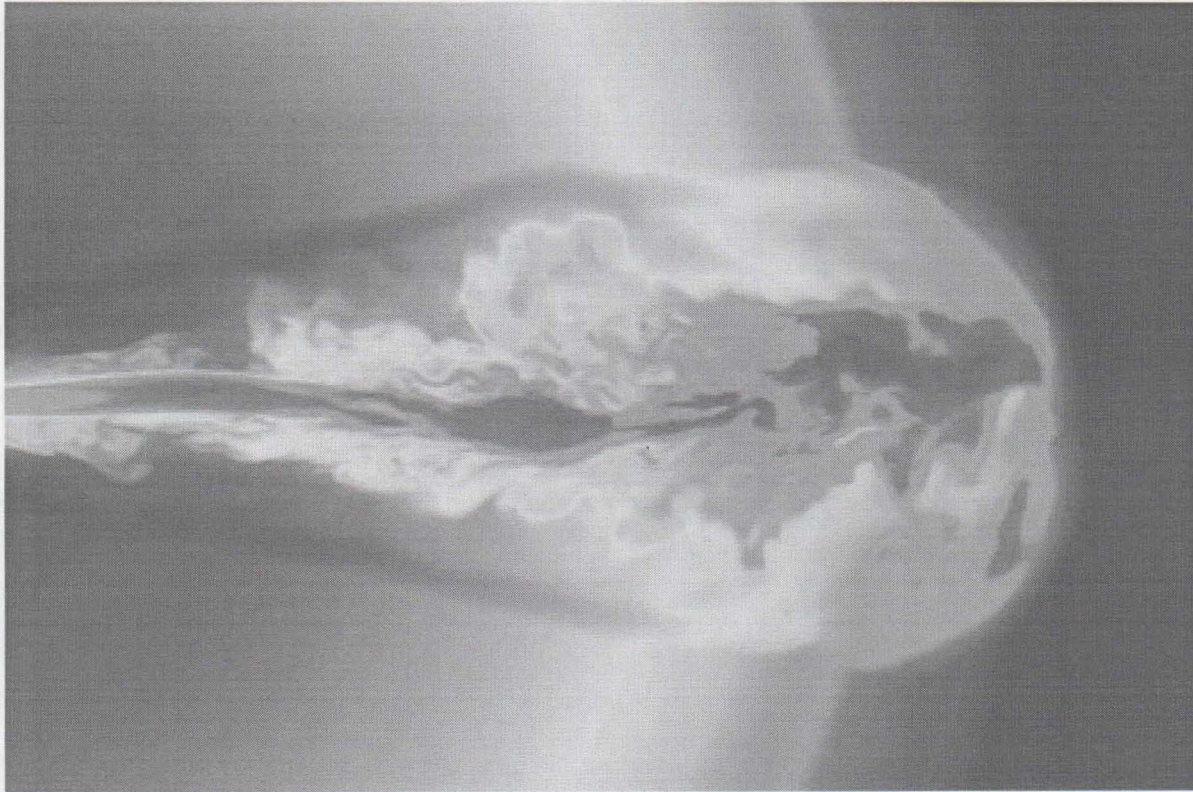
# Collapsar Model

- Supermassive star burns off H, becomes Wolf-Rayet star with He, Fe core
- Core burned, star collapses and forms black hole with matter accretion jets
- Jets shatter outer shell of star, creates hypernova
- Jets speed on and collide with other nearby material to create the subsequent gamma-ray burst



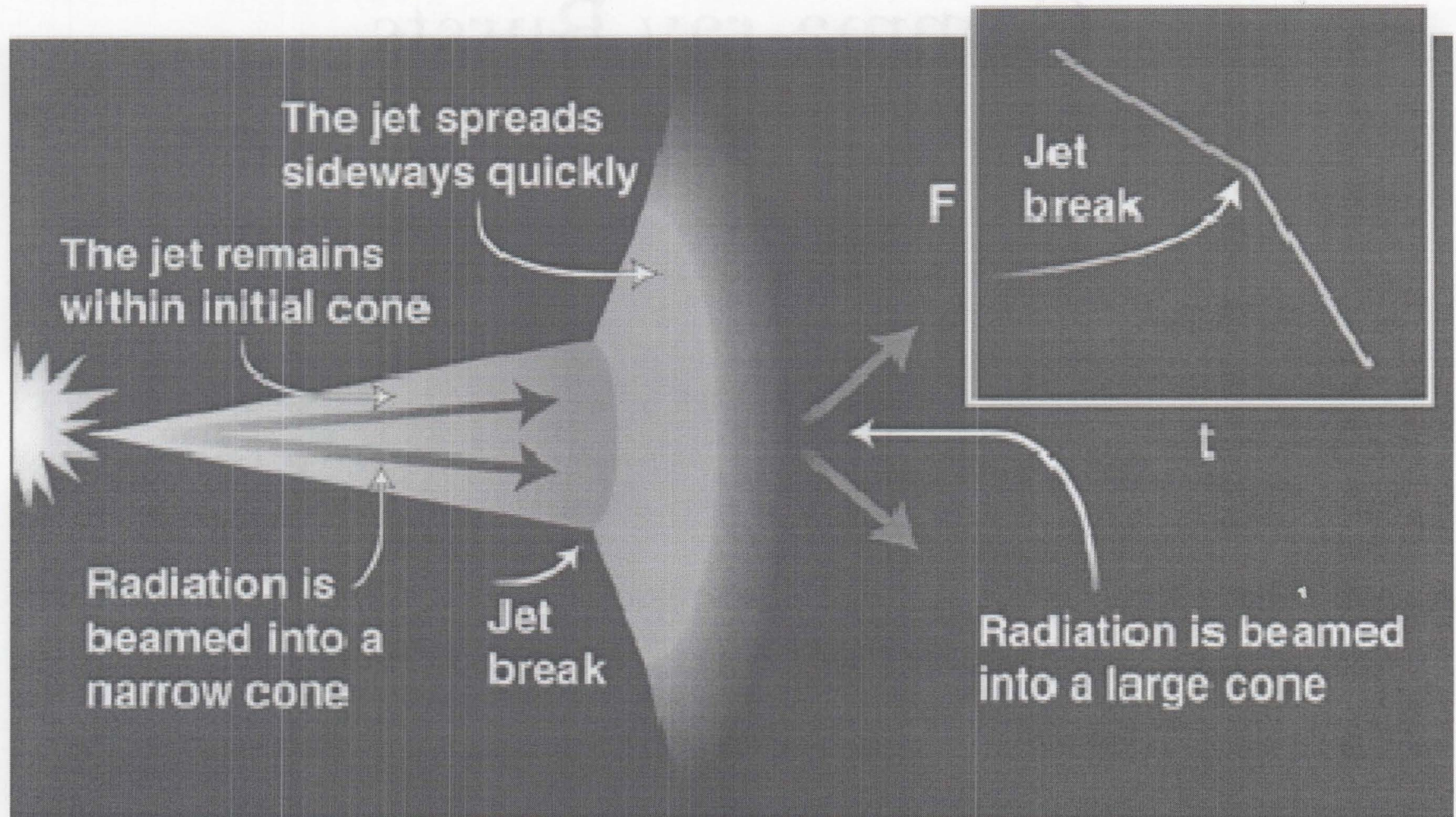


# Jet Simulation - Launched from a Collapsing Core





# GRB Afterglow Decay





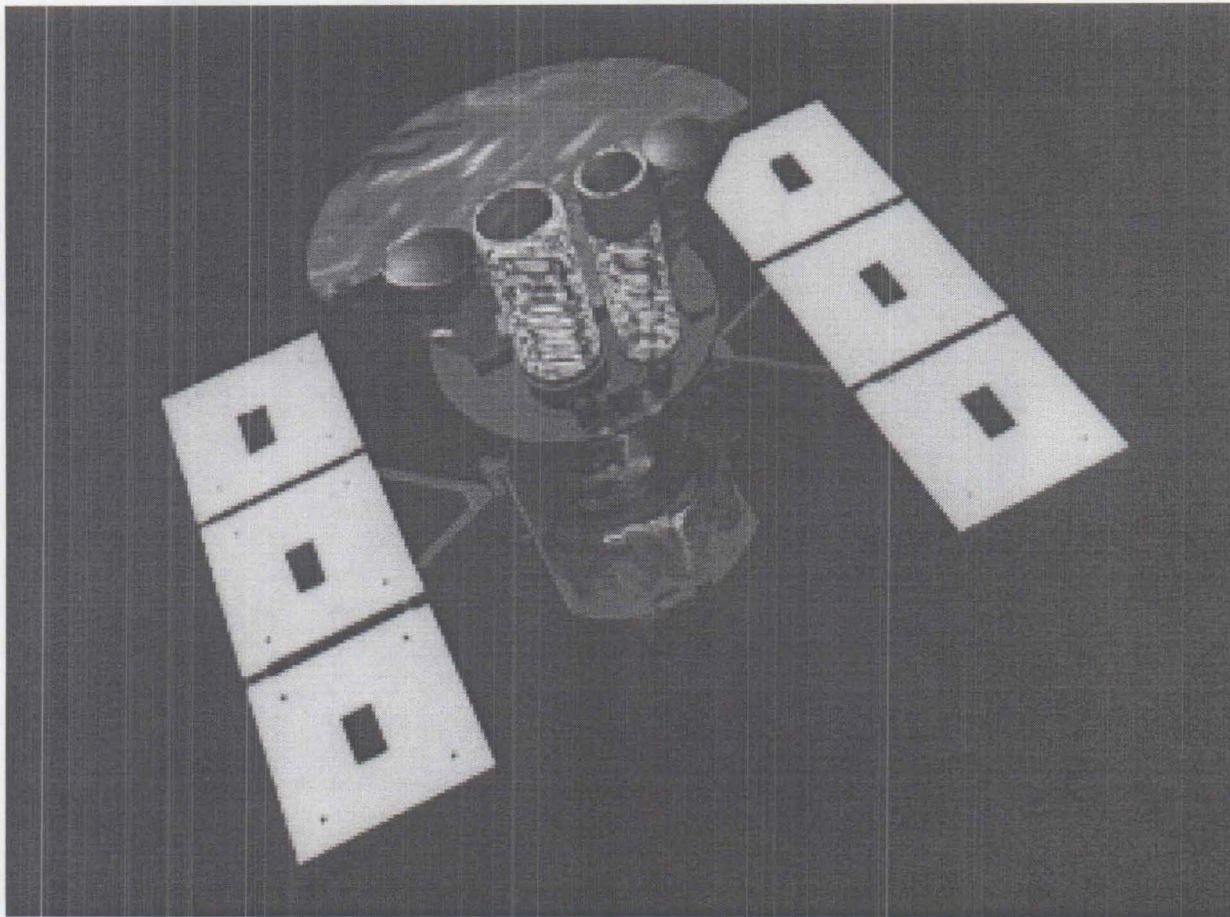
# Gamma-ray Bursts

- Or the death of life on Earth?



# **SWIFT - GRB Satellite**

**Launched Nov. 2004**





# The Sun in X-rays - Yokoh



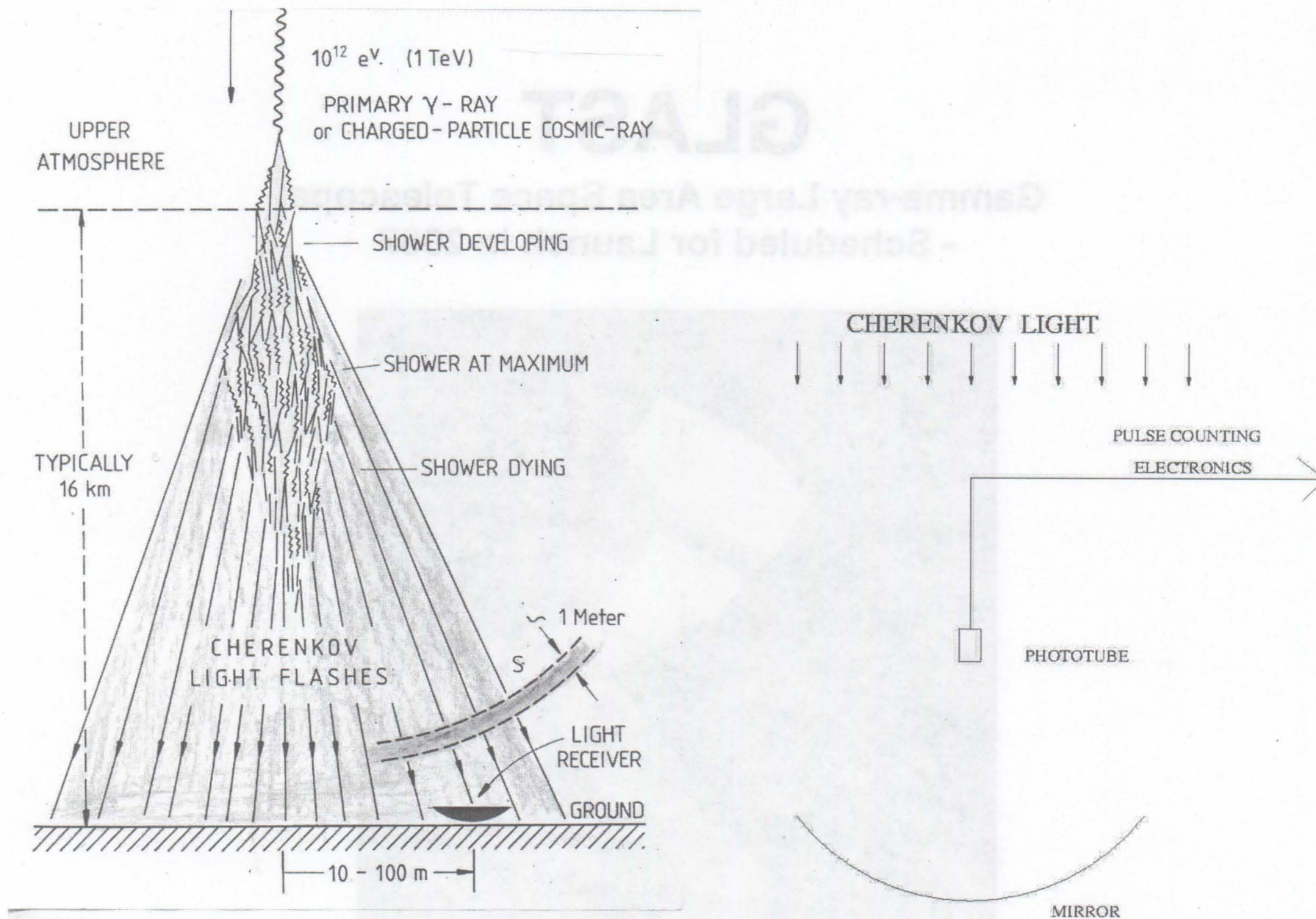
# GLAST

**Gamma-ray Large Area Space Telescope**  
**- Scheduled for Launch in 2007**

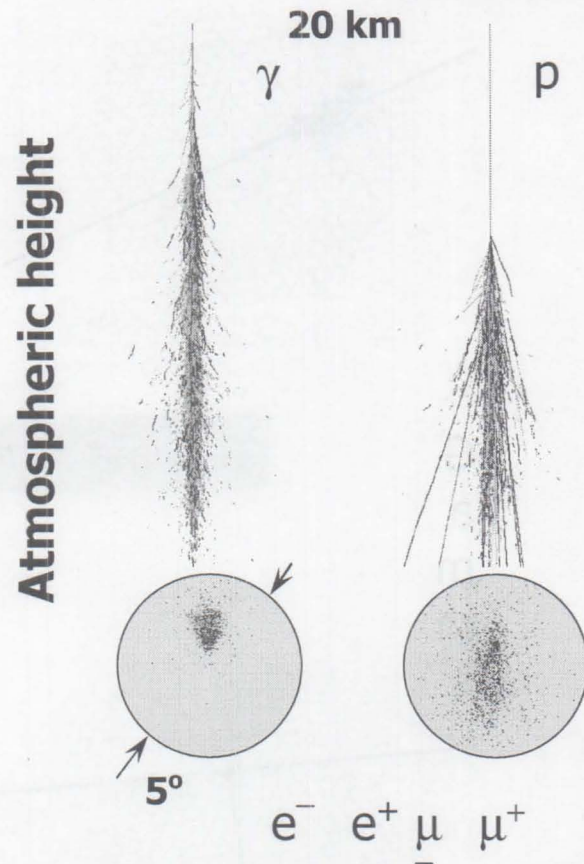


Credit: Hytec



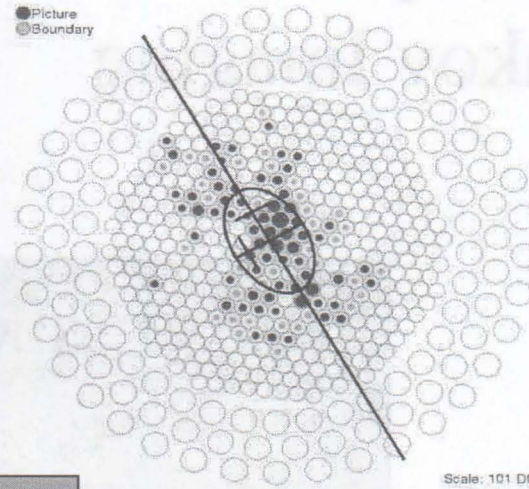
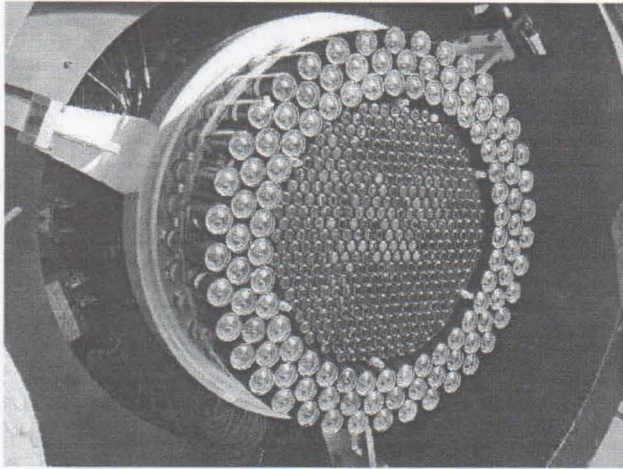


# Second Generation Systems Atmospheric Cherenkov Imaging

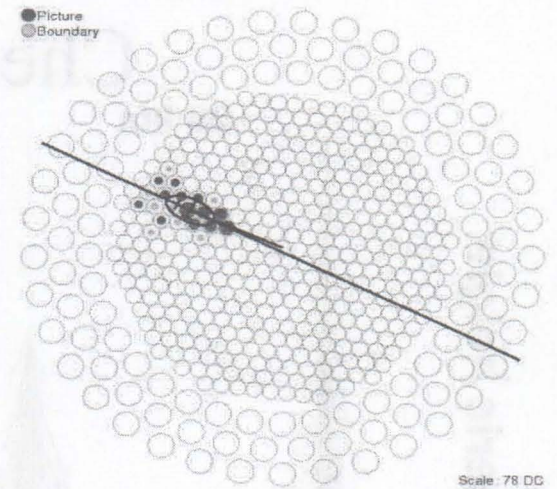


Cherenkov Imaging gives the ability to distinguish compact images of gamma-ray showers from more irregular images from hadronic showers

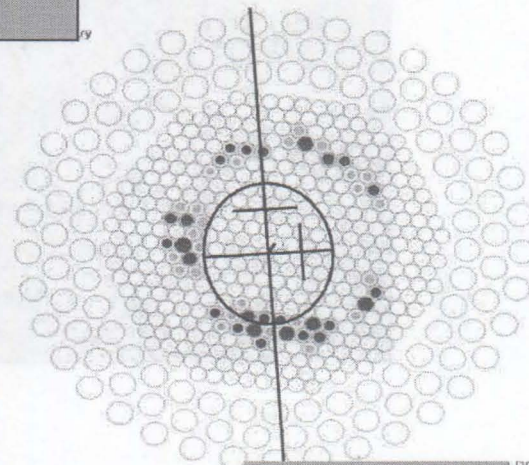




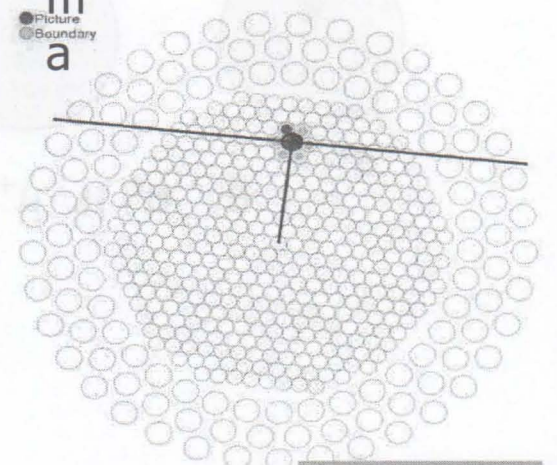
Hadron



Gamma ray

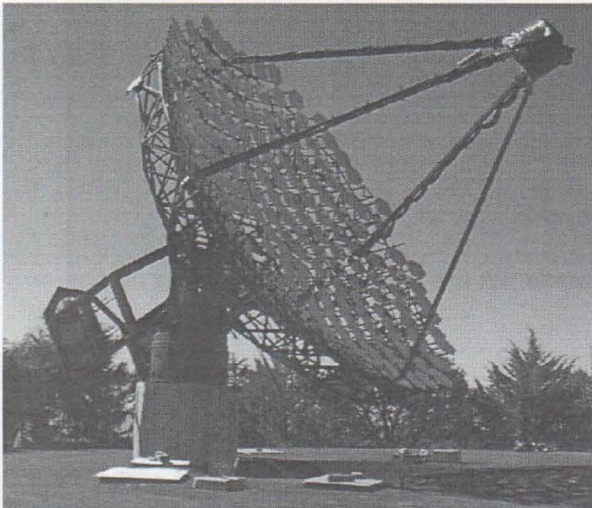


Muon Ring



Sky Noise

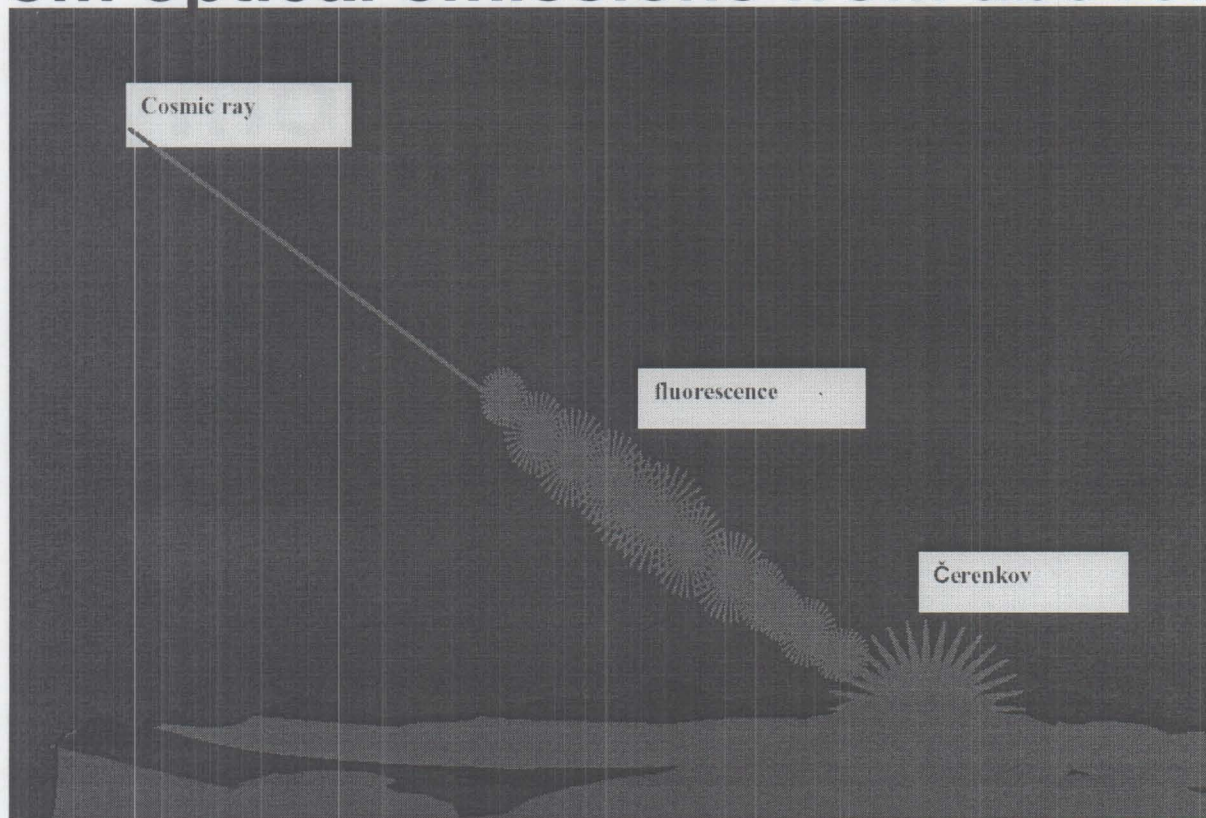
Types of images  
seen by atmospheric  
Cherenkov camera





# EUSO & OWL

Observe Extremely H.E. Cosmic Rays  
from optical emissions from above:

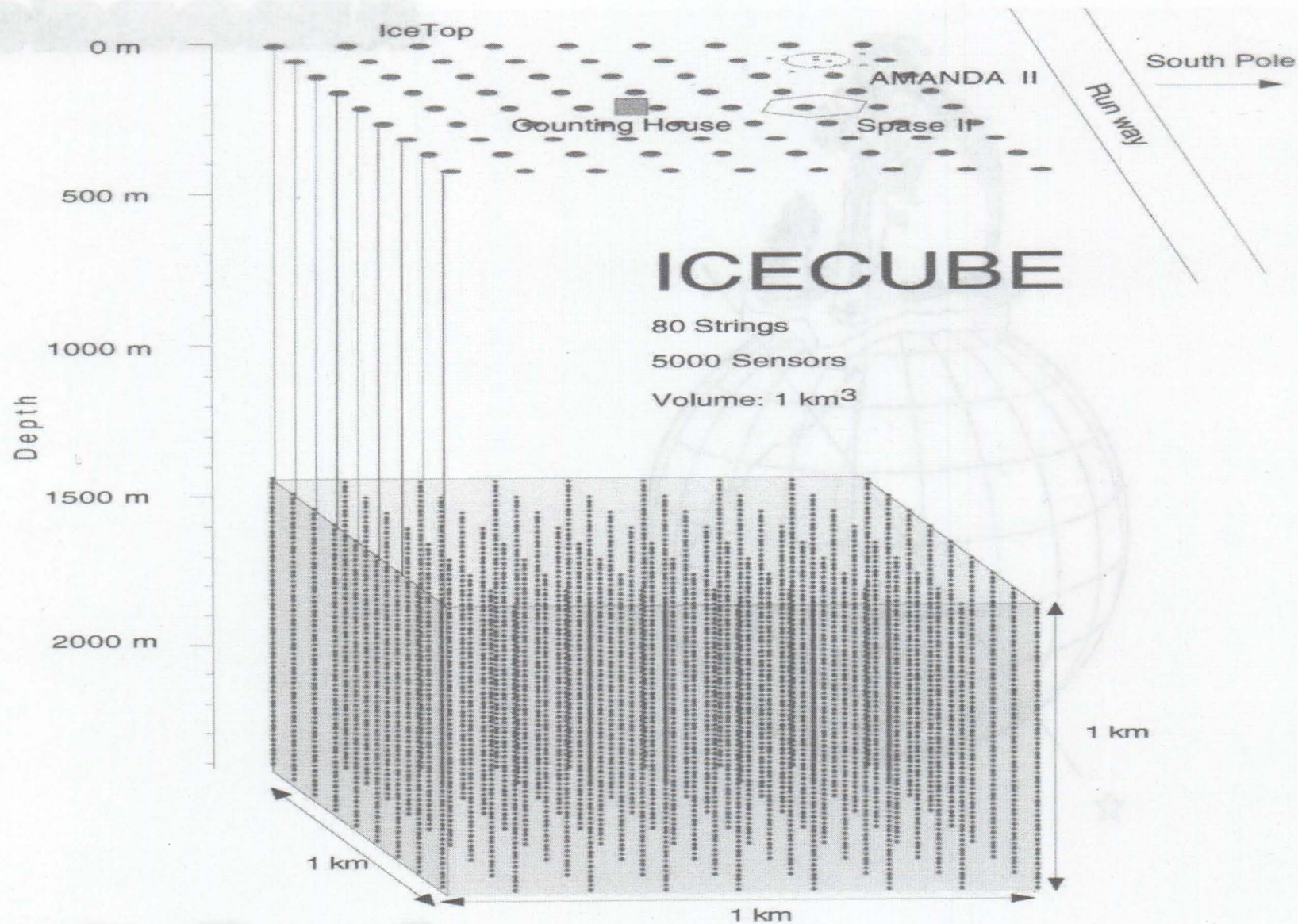




# Neutrino Astronomy

# IceCube

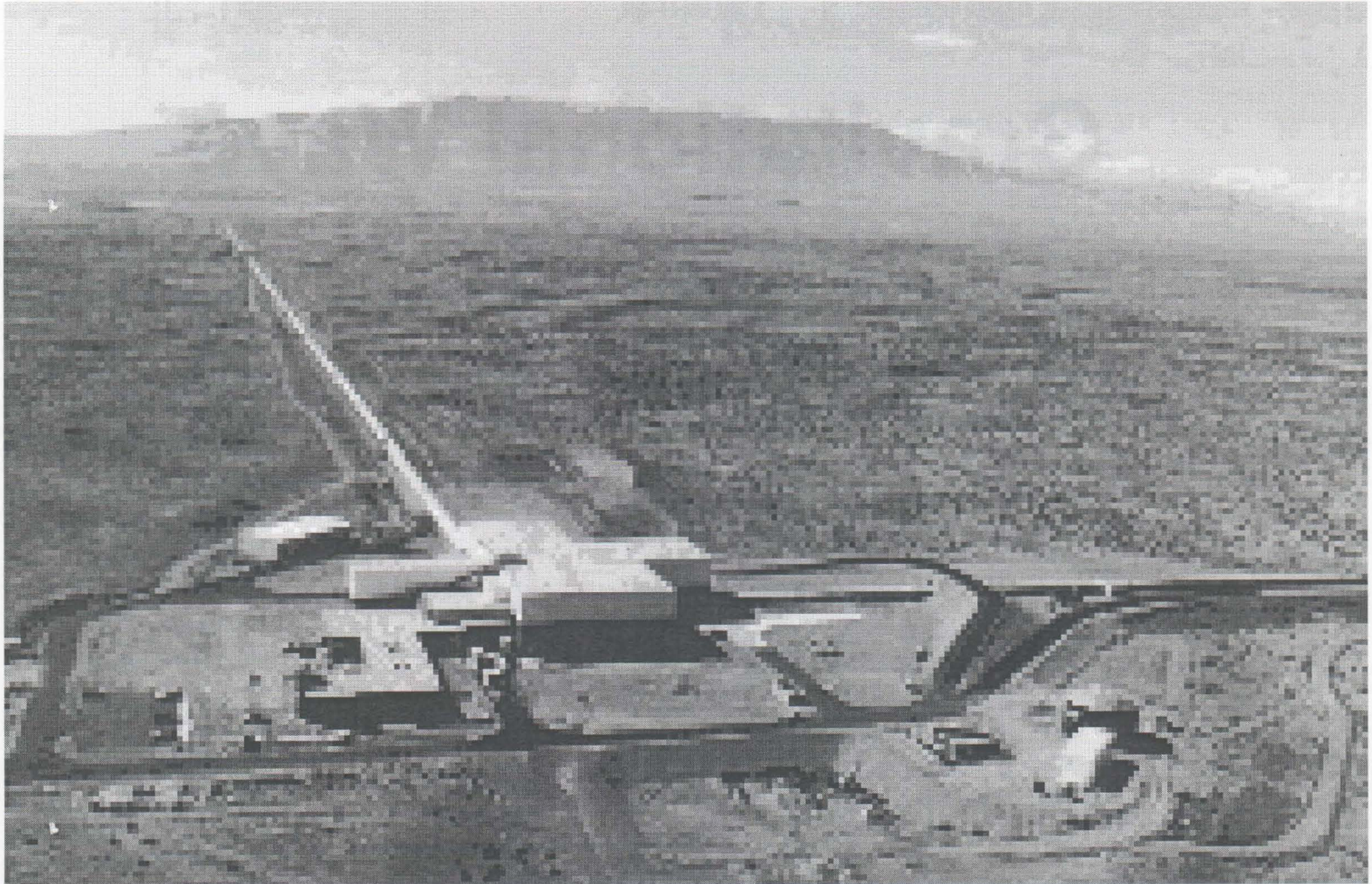




# **Gravitational Wave Astronomy**

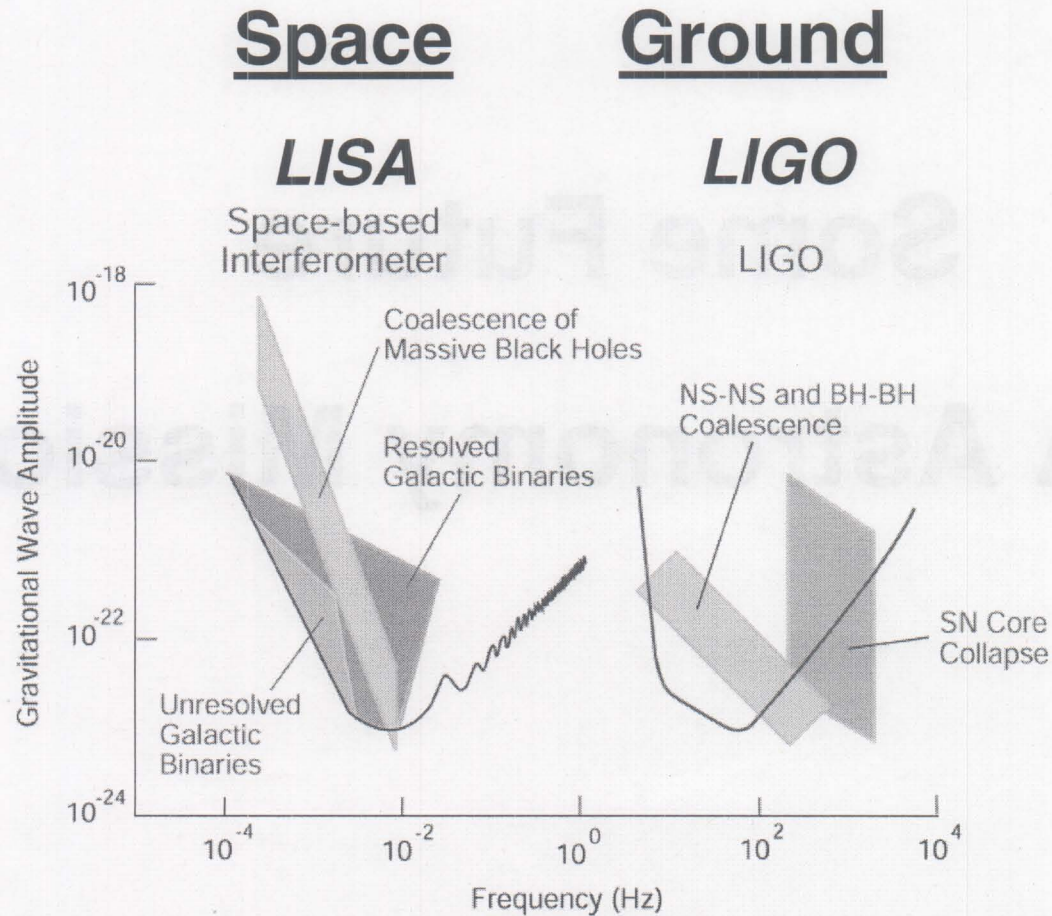


# *LIGO*





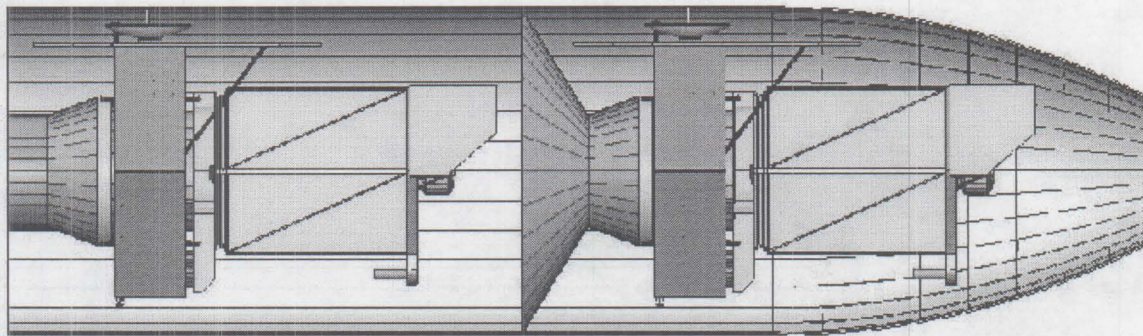
# Gravitational Wave Astronomy





# **Some Future NASA Astronomy Missions**

# Constellation – X

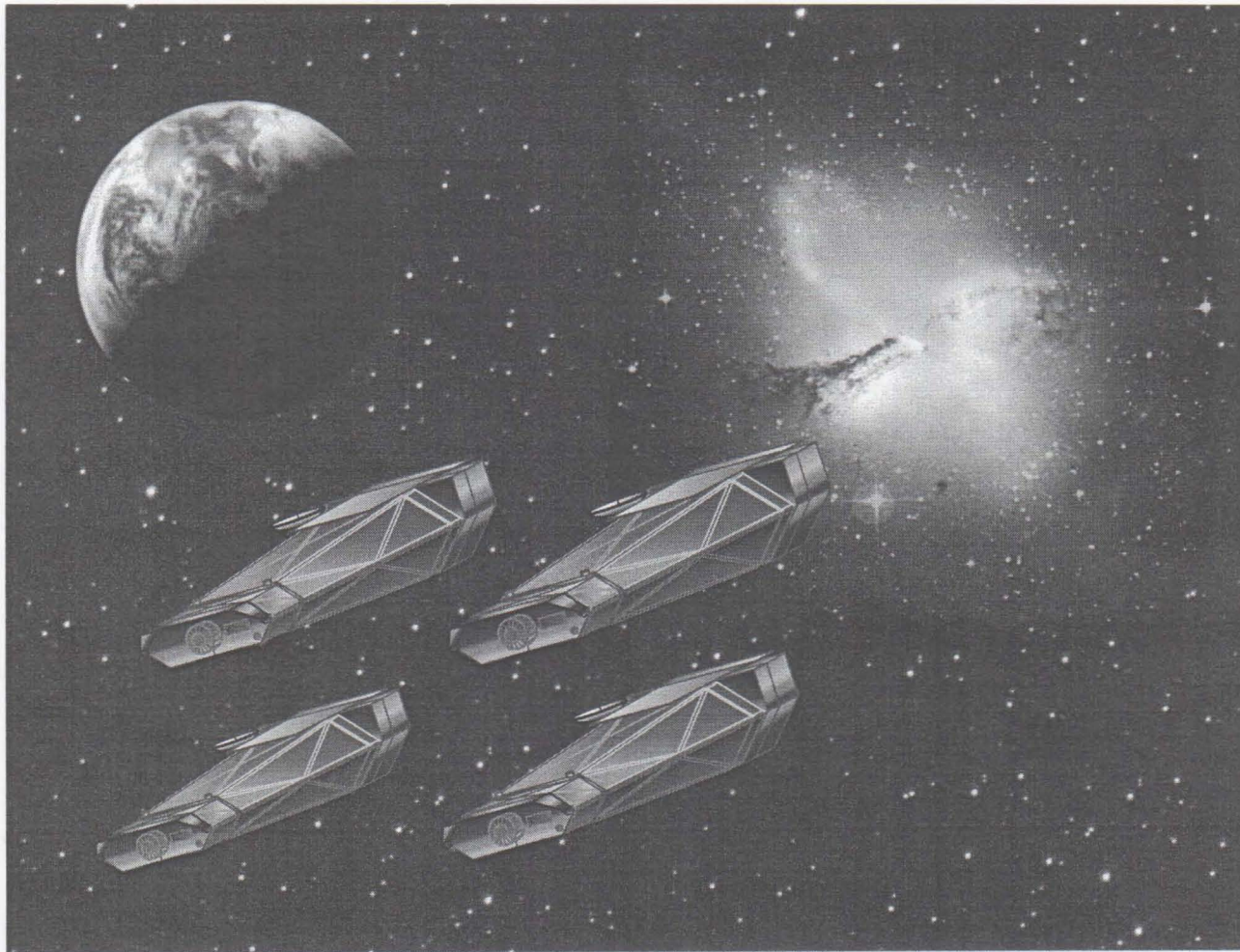


## Two Spacecraft in Atlas V Shroud

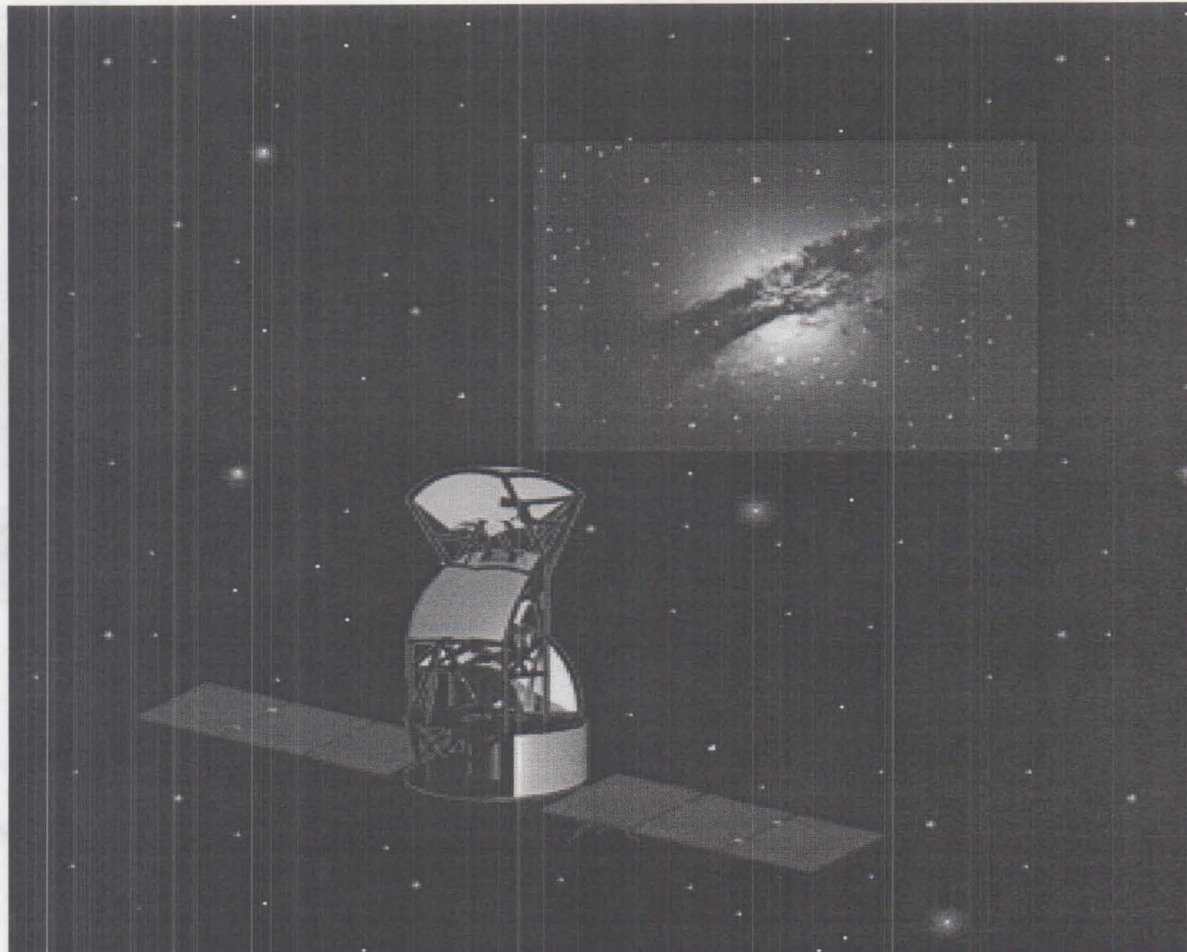
Atlas V DM Launch Configuration - Side View



# The Constellation-X Mission (Four Spacecraft)

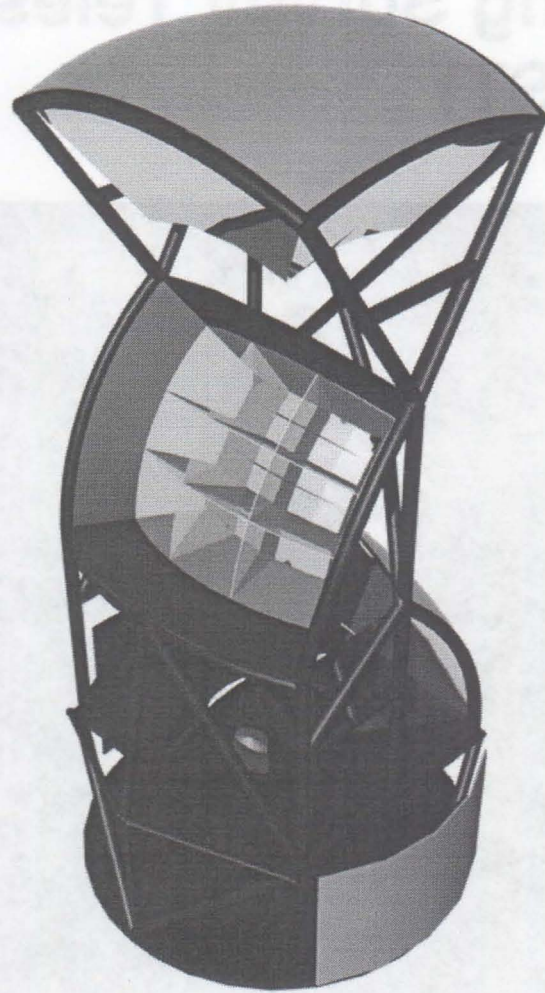


# **Energetic X-ray Imaging Survey Telescope (EXIST)**

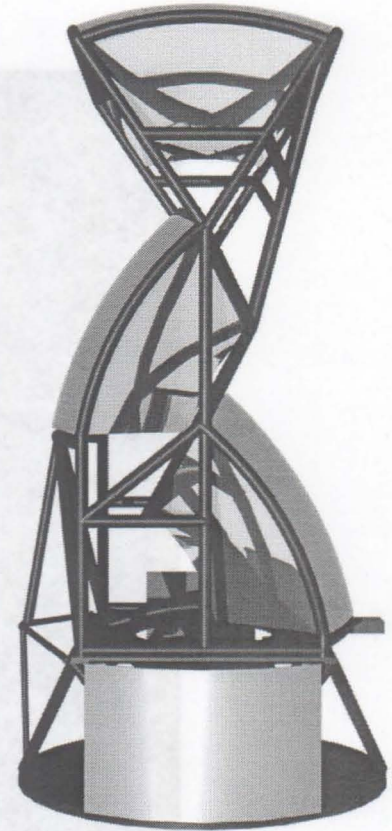




# EXIST



**Detector-collimator & Telescope**



**Side View**

**The End**